The AMSAT® Journal

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SO-35 in Orbit! After a month delay due to high level winds and minor technical problems, Boeing successfully launched the three-ton Advanced Research and Global Observation Satellite (ARGOS) for the U.S. Air Force at Vandenberg Air Force Base at 09:29 UTC, on 23 February 1999. The same Delta II rocket carried two additional NASA-sponsored satellites: the Oersted satellite for Denmark and South African-built SUNSAT (SO-35) microsatellite. See page 4 for additional SO-35 details. (photo by Thom Baur, Boeing)

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AMSAT at 30

by Keith Baker, KB1SF

In March 1999, AMSAT celebrated its 30th anniversary. Does it really seem like it was now 30 years ago that George Jacobs, W3ASK, addressed the Communications Satellite Corporation (COMSAT) Amateur Radio Club in Washington, DC on the subject of amateur radio communications in space? After describing the phenomenal success of the original OSCAR satellite program that launched the very first amateur radio satellites, George urged the COMSAT club to pick up where the original OSCAR group had left off.

It didn't take them long. Soon thereafter, the AMSAT organization as we know it today was organized. Like so many of our individual satellite project's beginnings, our organizational beginnings were also certainly inauspicious enough. It all came together at a meeting in the Washington, DC apartment of Dr. Perry Klein, K3JTE (now W3PK). That meeting included Jan King, K8VTR (now W3GEY); Harry Helfrich, W3ZM; Jim Puglise, W3CBJ, Cap Petry, W3AWN; George Kinal, K2MBU; Dr. Klein and our recent Past President and current Board Chairman, Bill Tynan, W3KMV (now W3XO). The group was incorporated as a non-profit organization in the District of Columbia on March 3, 1969, and AMSAT, The Radio Amateur Satellite Corporation, was officially born.

By any measure, what has happened since that first meeting in Perry's apartment back in 1969 is nothing short of phenomenal and has had a major impact on the world as we know it. Not just as Amateur Radio Operators, mind you, but as citizens of Planet Earth.

For it was AMSAT (and its later International cousins) that helped the rest of the world's communication engineers perfect the idea of a "satellite transponder"...that device which, in its modern day form, now relays television pictures, telephone calls and, yes, even that modern-day miracle...Internet traffic...from faraway places in near-real time into our homes and offices.

It was AMSAT that first flew CMOS devices in space. It was also AMSAT's experimenters (largely out of necessity because the organization couldn't afford anything else!) who first discovered that "off the shelf" electronic components often work just as well, and in some cases, better in space than those components that are tested to near destruction in the pricey pursuit of a "space rated" label.

And, it was AMSAT, along with the University of Surrey in England, that worked with ArianeSpace in their search for ways to take advantage of the many unused small "nooks and crannies" on launch vehicles where traditionally only useless (for communication purposes) ballast had been placed. The result was a method to launch a new series of small, lightweight satellites AMSAT called MICROSATS as well as the slightly larger UoSats.

Little did AMSAT's experimenters realize at the time that their MICROSAT and UoSat designs would also spawn a whole new multi- BILLION dollar, world-wide space industry using large constellations of small low Earth orbiting satellites. Today, their ideas live on, many having been incorporated into commercial projects with commonly recognized registered trademarks such as Iridium and OrbComm. To add icing to the cake, AMSAT's first fleet of MICROSATS and UoSats, still largely operational, have since been joined by a number of others.

It is often said that imitation is the most sincere form of flattery. The number of multi-billion dollar corporations now set up around the globe who are in pursuit of these same goals is living proof that AMSAT's original idea (and the way we implemented it) had merit. What's more, a number of these same organizations are now actively seeking out AMSAT's experimenters for advice and counsel to learn " how it's done". It's also noteworthy that most of our experimenters are usually eager and willing to freely share their learning.

What's even more amazing to me is that a number of these well-heeled commercial companies have yet to launch a single satellite! Conversely, I had the personal honor a few weeks back to help add an OSCAR designator to South Africa's SUNSAT satellite, bringing the OSCAR satellite tally to 35. And the 34 others that preceded SUNSAT didn't even include the large number of amateur radio satellites that have been built and placed into orbit by others!

Yes, any way you cut it, the string of successful AMSAT satellites launched since our inauspicious beginnings over 30 years ago speaks volumes about the vision, tenacity, courage and convictions of our members as well as that of our international partners around the world. As we stand poised on the dawn of a new century, there is no doubt in my mind that another AMSAT-NA President, writing some 30 years hence, will once again point to the outstanding contributions this unique organization has made, and will continue to make, to the advancement of space technology and space science.

Needless to say, I'm honored to walk among such a prestigious group as your President. My sincere hope is that the next 30 years will be as exciting and productive as the first 30 have been. ■

AMSAT 30th Anniversary: Frank Bauer, KA3HDO (right) presenting AMSAT-NA President Keith Baker, KB1SF (left), with a plaque from the NASA Goddard Space Flight Center (GSFC). The plaque recognizes the long and successful history that AMSAT and GSFC have had working together on the AMSAT-OSCAR program. (photo by Dick Daniels, W4PUJ)

SUNSAT-OSCAR 35 Successfully Launched

[via AMSAT News Service (ANS)] After more than a month of delays and aborted launch attempts, a Delta II rocket carrying the South African SUNSAT Amateur Radio satellite successfully lifted off from Vandenberg Air Force Base in California at 0929 UTC, 23 February 1999. From the launch site, Cliff Buttschardt, K7RR, (via John Curtis, W7RAQ) first reported the good news to ANS: "Success at last! The rocket carrying SUNSAT was launched this morning. The launch was a spectacular sight with the rocket lifting straight up, heading slightly west then turning south before disappearing from visual sight."

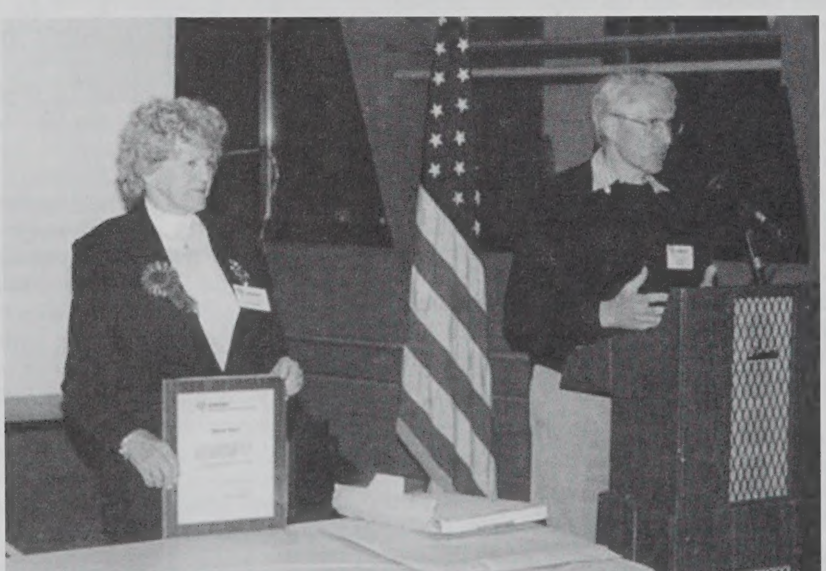
Following the launch, the AMSAT-BB was active with congratulations for the SUNSAT team. John Mock, KD6PAG first reported receiving the downlink, noting "the bird was S-9 at times." After hearing SUNSAT's signal in Great Britain, John Melton, G0ORX, passed on "congratulations to SUNSAT!" Phil Karn, KA9Q, reported seeing the launch from the front of his house in San Diego. KA9Q told ANS that he "picked up the yellow SRB plumes about a minute after launch as it rose above the usual low elevation haze."

Shortly after launch, AMSAT-NA President, Keith Baker, KB1SF, issued the following release: "On behalf of AMSAT-NA, please pass along our sincere congratulations on the successful launch and activation of SUNSAT in orbit. I know there are many hams around the world who have been patiently waiting for the launch of this satellite and I am personally looking forward to the unique on-orbit capabilities that it will bring to us. Once again, our sincere congratulations and thanks to all the SUNSAT team for a job well done!"

SUNSAT, which stands for Stellenbosch University Satellite, takes its name from the South African university whose students constructed the payload. The University of Stellenbosch, situated in the second oldest town in South Africa, is not far from the southern tip of the African continent just east of Cape Town. The university has in an enrollment of over of 14,000 students.

The SUNSAT package includes digital store-and-forward capability and a voice 'parrot' repeater system that will be used primarily for educational demonstrations. The satellite has two VHF and two UHF transmit-receive systems. Current downlink activity from SUNSAT is on 436.250 MHz, using a FSK Bell 202 format at 1200 baud. A complete description of SUNSAT (along with photographs) is available in the September/October 1998 issue of *The AMSAT Journal*.

The SUNSAT command team, headed by Garth Milne, ZR1AFH, reported signals were received from the new satellite during the very first orbit. "We uplinked commands to SUNSAT and were overjoyed to hear UHF telemetry start at 1200 baud, just as we wished," said ZR1AFH. However, after 12 hours in orbit, uplinking would become much more difficult, mainly because the spacecraft was still tumbling. K7RR, reported that after making many changes including increasing power and installing new antennas on the ground, the Vandenberg command team received loud and clear return signals from the bird.



AMSAT 30th Anniversary: Jan King, W3GEY, presenting plaque to Marie Marr for her contributions as a technician on the projects AMSAT-OSCAR 6 through AMSAT-OSCAR 13. Marie now lives in Florida and was brought to the AMSAT 30th Anniversary Celebration as a surprise through the efforts of her family. Seven of Marie's family attended the event and credit for organizing the surprise goes to her grandaughter Kim. (photo by Dick Daniels, W4PUJ)

Ground control at Stellenbosch University is now currently busy with the commissioning of the satellite, including deployment of the gravity boom to help stabilize the bird.

During the commissioning phase, amateurs are kindly requested to avoid using SUNSAT uplink frequencies. The SUNSAT downlink will only be active when the satellite is within range of the ZS1SUN groundstation. Amateurs are invited to monitor or record these telemetry downlinks. At this time the command team is planning general Amateur Radio service by the end of March 1999.

Responding to a question from KB1SF, representatives of the SUNSAT team have now requested that an OSCAR number be assigned to help designate their new spacecraft. KB1SF also passed along congratulations from all AMSAT-NA members to the SUNSAT team on their outstanding success.

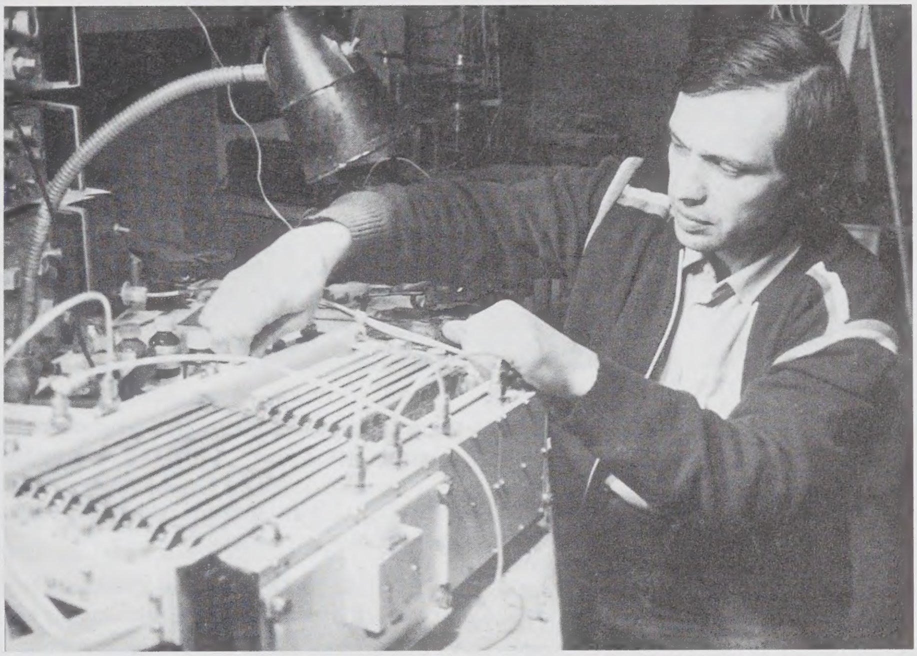
The assignment of consecutive OSCAR numbers to new Amateur Radio spacecraft is a tradition that dates from the launch of the very first Amateur Radio Satellite — OSCAR-1. In order for an OSCAR number to be assigned, the satellite must successfully achieve orbit and one or more transmitters must be successfully activated in the Amateur Radio bands. Then, the builders/owners of the satellite must formally request that a consecutive OSCAR number be assigned to their satellite once the first two requirements are accomplished.

Speaking for the SUNSAT team, Professor Garth Milne, ZR1AFH, SUNSAT Project Leader, said "the Amateur Radio services on SUNSAT are our thank you to the ham radio community for the legacy it has left for us all. We would thus be honored if SUNSAT could be recognized as an OSCAR satellite, and suggest the designation SUNSAT-OSCAR 35, abbreviated to SO-35 be used."

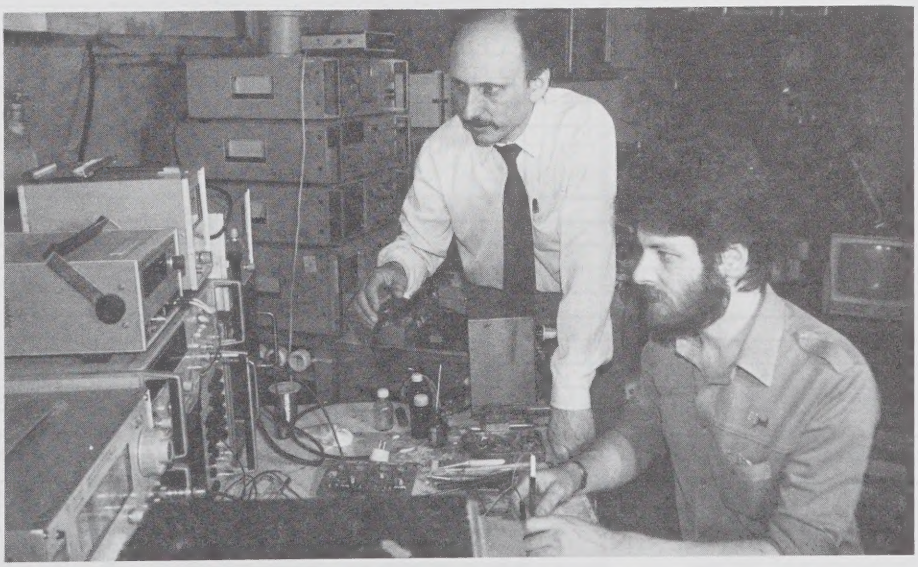
KB1SF has informed ANS that, in the light of this information, it is now appropriate to refer to the new amateur satellite as SUNSAT OSCAR-35 or simply SO-35.

For more information on SUNSAT, visit the following URL: *http://sunsat.ee.sun.ac.za*

[ANS congratulates the SUNSAT team and thanks Clifford Buttschardt, K7RR, Garth Milne, ZR1AFH, Sias Mostert, ZR1MS, and the ARRL for this information] ■



Recently, Andy Mirinov, RK3KPK and Pat Gowen, G3IOR sent us some photographs from AMSAT-Russia's history. This photograph shows Victor Samkov who was Chief Designer of RS-10.



In another photograph are Aleksandr Papkov, UA3XBU (left) and Eugenij Levin (right), the chief architects of the RS-10 transponder. (photo courtesy of Andy Mirinov, RK3PKP and Pat Gowen, G3IOR)

Andy Thomas, VK5MIR Meets Amateurs in Adelaide

Tony Hutchinson, VK5ZAI

From left to right, Tony Hutchinson, VK5ZAI; Doug Tamblyn, VK5GA; Andy Thomas, VK5MIR; and Ivan Skewes, VK5HS.

US/*Mir* Astronaut Andy Thomas, VK5MIR was back in Adelaide, South Australia visiting his parents over the Christmas and New Year summer when I caught up with him. Andy stated that before he returned to Houston he would like to meet those amateurs who spoke to him while on *Mir* and any others who may be interested. After a generous offer by the West Torrens Council (a suburb of Adelaide) to loan us their meeting room for the occasion, the meeting date of January 20th was set aside. It was an evening I'm sure that everyone who attended will remember.

A welcome address was given by the President of the Wireless Institute of Australia, South Australia Division to over 300 guests, some coming from as far away as Alice Springs and Melbourne. The evening was then handed over to Andy who first gave an insight into his selection and training for his four-month stay in space. This was followed by an in flight video of the launch, his time on *Mir* and then the return flight on the shuttle. Andy gave a running commentary with the video saying that he prefers to do it that way if possible. Some of the scenes on this video were quite spectacular. He then answered questions for nearly an hour after which the Acting Mayor invested him with the City of West Torrens Civic Award. Supper was then served for those who made voice contact with Andy so he could meet them in person followed by many photos and autographs.

The evening finished with another supper for about eight of us in the Mayors office after which I dropped Andy off at his home about 12:45 am. It is difficult to describe the evening in words, as Andy just seems to have a natural way of captivating his audience and shows such a genuine interest in the questions people asked him. In closing, if you ever get a chance to hear Andy speak, do not miss it. ■

AMSAT Nets

Prepared by Andy Reynolds, WB9IYT

VHF/UHF Nets	Day	Local Time	Frequency (MHz)	Location	Net Control	Additional Comments
AMSAT Net Boston/Heavy Hitter AMSAT Net	Thursday	2030	146.640	Waltham, MA	Ernie MacLauchlan, K1ELA	
ARK-LA-TEX QCWA/AMSAT Net	Monday	1930	146.670	Shreveport, LA	Roger Ley, WA9PZL	Opens with QCWA followed by AMSAT net
Central New York AMSAT Round Table	Monday	2000	146.880	Rome, NY	Randolph Baker, WA2EXJ	
Colorado AMSAT Net	Wednesday	2000	147.225	Denver, CO	John Gubbins, N0VSE	www.idcomm.com/personal/n0vse
			145.460	Boulder, CO		
			145.160	Colorado Springs, CO		
Cowley County Kansas VHF AMSAT Net	Sunday	2000	145.190	Wichita, KS	Ron Smith, N5SMJ	Greg N5ZHE reads ANS bulletins
Forth Worth Dallas Metroplex VHF Net	Friday	2100	147.140	Fort Worth, TX	Doug Howard, KG5OA	Check-ins, ANS, Rnd Tble, Swap
Houston AMSAT Net	Tuesday	2000	147.100	Houston, TX	Andy MacAllister, W5ACM	Satellite Feed via Hughes SBS 6, transponder 13b, 6.2 MHz and via Internet audio at www.amsatnet.com
Houston AMSAT Net via KU TVRO BUD	Tuesday	2100	146.880	Buckfield, ME	George Caswell, W1ME	100 Hz Tone
			146.670	Derry, NH		85 Hz Tone
			146.850	Bangor, ME		100 Hz Tone
Interstate Repeater Society AMSAT Net	Friday	2000	146.850	Derry, NH	George Caswell, W1ME	100 Hz Tone
			224.460	Derry, NH		
			449.625	Derry, NH		
Long Island New York AMSAT Net	Tuesday	2000	147.210	Long Island, NY	Ken Ernandes, N2WWD	136.5 Hz tone with 147.075 backup
Miss/Lou AMSAT Net	Thursday	2000	147.270	Vicksburg, MS	Eddie Pettis, N5JGK	100 Hz tone
Southeast Michigan AMSAT Net	Tuesday	2000	145.330	Detroit, MI	James French, KD4DLA	www.provide.net/~jsmyth
			224.580	Detroit, MI		
			442.800	Detroit, MI		
			1282.050	Detroit, MI		
Southern Arizona AMSAT Net	Wednesday	1900	146.280	Tuscon, AZ	Larry Brown, NW7N	100 mile repeater coverage
Southwest Ohio AMSAT Net	Tuesday	2000	145.110	Dayton, OH		
HF Nets	**Day**	**Time**	**Frequency (MHz)**	**Net**	**Net Control**	**Additional Comments**
75 Meter Regional AMSAT Net	Tuesday	2100 EST	3.840	East Coast	Al Tribble, W3STW	Ron Long, W8GUS, Alt NCS
75 Meter Regional AMSAT Net	Tuesday	2100 CST	3.840	Mid-America	Keith Pugh, W5IU	
75 Meter Regional AMSAT Net	Tuesday	2000 PST	3.840	West Coast	Cliff Buttschardt, K7RR	Jim Sheppard, K6OYY, Alt NCS
20 Meter International AMSAT Net	Sunday	1800 UTC	14.282	Pre-Net Warmup	Keith Pugh, W5IU	Wray Dudley, W8GQW, Alt NCS
20 Meter International AMSAT Net	Sunday	1900 UTC	14.282	ANS Bulletins (East)	Keith Pugh, W5IU	Wray Dudley, W8GQW, Alt NCS
20 Meter International AMSAT Net	Sunday	1930 UTC	14.282	ANS Bulletins (West)	Keith Pugh, W5IU	Wray Dudley, W8GQW, Alt NCS
15 Meter International AMSAT Net	Sunday	1900 UTC	21.280	ANS Bulletins	Wray Dudley, W8GQW	Jack Butler, KB7UZ, Alt NCS

The Experimental IHU-2 Aboard Phase 3D

Chuck Green, N0ADI; Peter Gülzow, DB2OS; Lyle Johnson, WA7GXD; Karl Meinzer, DJ4ZC; James Miller, G3RUH

IHU-2 is intended to act as a future replacement for the current COSMAC-1802-based flight computer (IHU) that has flown on all previous Phase 3 missions and indeed controls the AMSAT Phase 3D satellite. The IHU-2 is aboard Phase 3D as a proof-of-technology experiment. Although in contact with other Phase 3D sub-systems, it will not manage anything mission critical. These notes document the design from inspiration in September 1997 to running hardware/software, April 1998.

Introduction

IHU-2 is an experiment to use currently available, standard-process technology components to implement a higher-performance IHU, and running an enhanced version of IPS to enable software re-use. It provides a test-bed for a one-wire-per-module control/status system, implements a CMOS imager for navigation testing, and is very power efficient. Finally, it includes a DSP-style, up to 20 kilobit/sec radio modem experiment to better balance memory capacity to uplink/downlink data rates.

Background [WA7GXD]

In late 1997, Peter Gülzow circulated a note about a CMOS image sensor based on photon rate rather than charge accumulation and suggested its characteristics might make it a good candidate for starfield navigation experiments as well as capturing images of the first moments of life of Phase 3D. At about the same time, Digital Equipment Corporation (since partly absorbed into Intel) announced a highly integrated version of their StrongARM processor, the SA-1100. Karl Meinzer had just obtained a desktop PC based on Digital's StrongARM technology. James Miller had been using such a computer for years for developing AO-13 spacecraft management software and, along with the P3 command team, managing that spacecraft. Lyle Johnson had just made a decision to use the SA-1100 in a major product development at his work. Phase 3D had missed the AR-502 launch. There were discussions on AMSAT-bb and elsewhere about missions beyond Phase 3D. Chuck Green had finished building a lot of flight boards for Phase 3D and seemed to have some bandwidth available. Lyle was headed for three weeks vacation in New Zealand.

As so often happens, these seemingly unrelated events were the mutual catalysts that led to a small group of us discussing, designing, building and debugging a major new spacecraft computer for inclusion on Phase 3D!

Why an IHU-2?

The IHU flown on previous Phase 3 missions, and which will fly on Phase 3D, is based on the COSMAC CDP-1802 processor. UoSAT-1 and UoSAT-2 also used the 1802. Originally developed by RCA in the mid-1970s, this processor is currently made by Harris. Sandia National Laboratories (US) spun a radiation-hardened version circa 1980, and AMSAT had the good fortune to obtain a small number of them for the Phase 3 programme. In 1994, as we worked on the Phase 3D IHU, it became clear that these processors were long obsolete, and the

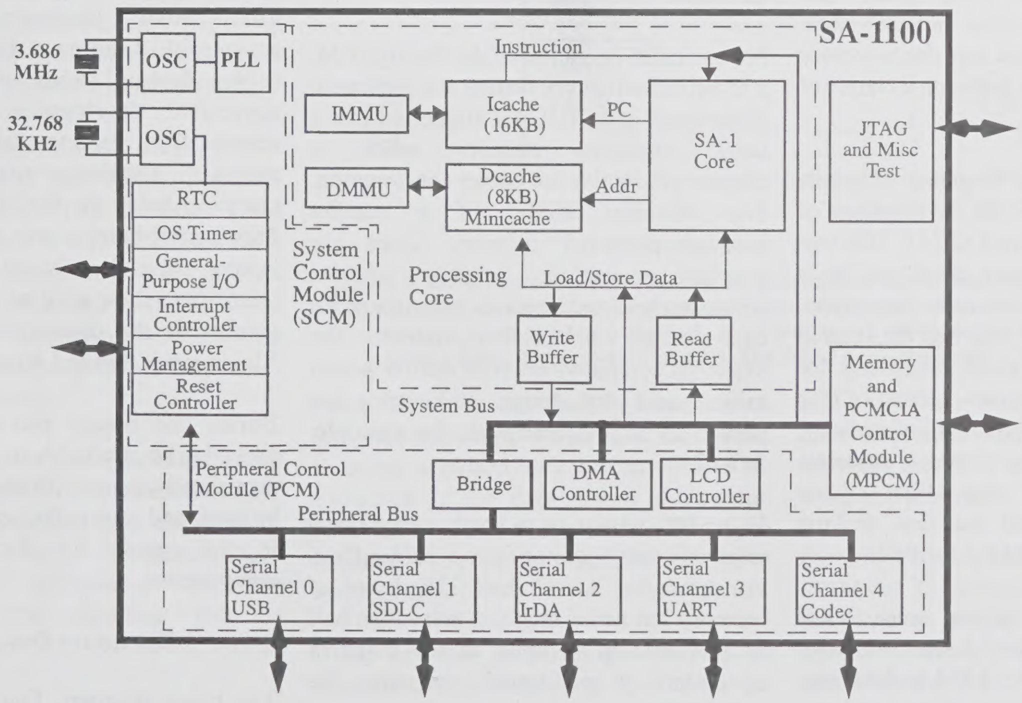


Figure 1. SA-1100 Block Diagram. The StrongARM SA-1100 implements most of a computer system on one chip! Capable of up to 200M instructions/s yet consuming only 200 mW, which reduces pro-rata with clock speed down to 0 Hz. The IHU-2 uses all the elements shown except RTC, DMA, LCD and Serial 0,1,2. All input/output is via the GPIO system at the left, and Memory Control on the right. Serial 3 is used for ground test at 115,200 baud; Serial 4 is used as a one-wire bus system. (C)1998 Intel Corporation.

rad-hard versions would no longer be obtainable. Indeed, the CPU chip in the Phase 3D IHU was fabricated in 1983!

Immediately after the Phase 3D IHU was brought to life in 1995, the I/O multiplexer was designed. While various proposals had been made, none seemed acceptable to reliably replace the parallel wiring that controls the various modules on Phase 3D and provides status. The wiring bundles in Phase 3D are extensive, massive and complex. More than 200 wires fan out from the multiplexer to destinations all over the spacecraft.

The CAN bus implemented on Phase 3D offers some promise of relieving wiring complexity. In fact, many experiments on Phase 3D are tied together by the CAN bus, and some of them rely solely on it. But the CAN protocols require a processor and the simplest systems continuously draw over 100 mW of spacecraft power. However, this situation is improving with the growing popularity of the CAN standard. Current rad-hard processors are extremely expensive, or use a lot of power, or both.

Early Discussions

As the need for a new IHU became clear, discussions were held over the Internet as well as one-on-one, about the processor technology, memory complement and feature set that would make the unit viable. Key to these discussions was the processor choice. Step back, for a moment, a couple of decades.

An eerily AMSAT-like sequence of events in the mid 1980s led to the development of the Acorn RISC Machine (ARM). This was a 32-bit RISC processor developed by a team of four people at Acorn Computers, Ltd. [1]. Acorn at the time was the leading UK manufacturer of small computers for education and home use. Goals of the processor design included simplicity, low-power operation, and moderate performance at low cost. First silicon appeared in 1985 and the first desktop computer using the ARM-2 in 1987.

In 1990, Apple, Acorn and VLSI Technology co-founded Advanced RISC Machines to exploit the ARM architecture. This was to be a fabless company, and was an early embodiment of the now-popular intellectual property (IP) semiconductor business paradigm.

The ARM processor has evolved over the ensuing years. In 1994, Digital Equipment licensed the ARM technology with an agreement to dramatically increase its performance. It resulted in the StrongARM processor in 1996, which Acorn themselves immediately incorporated into their flagship product, the Acorn RISC PC.

The StrongARM is a 32-bit RISC processor with on-chip instruction and data cache, a memory management unit (MMU), and the ability to deliver over 200 MIPS sustained performance while consuming about 0.5 watt. This compares to, for example, a *mobile Pentium* which delivers similar performance but uses nearly 8 watts.

In September 1997, Digital announced the SA-1100 StrongARM chip. This includes the StrongARM SA-1 core, but adds on-chip memory interfaces, interrupt controllers, timers, serial ports and numerous other auxiliary and peripheral functions. In spite of the increased functionality, it still offers over 200 MIPS of processing power, and at a lower 0.2 watt power consumption. It is a fully static part (i.e. can be clocked down to 0 Hz).[Internet reference 10.5] See Figure 1.

After consideration of various processors, the group decided to explore a design based on the SA-1100. Once that decision was made, the memory size and technology were discussed.

For optimum operation of the StrongARM, a 32-bit wide memory system was indicated. Experience with RUDAK suggested that a large, protected memory space is counter-productive for power consumption. The Microsat model of a smaller hardware-protected memory space for program execution, coupled with a software-protected larger memory space for data storage, was followed instead. The MicroSat computers are comparative power misers, and the design philosophy has proven to be scaleable with, for example, AO-27.

Using IPS, with roots in Forth, meant that a relatively small memory size would suffice. For example, AO-13 had 32K bytes of memory but never required more than half of this amount in spite of the complex operations it performed operating the spacecraft.

The memory size decided upon was 128K x 32-bit of hardware protected memory (EDAC) and 8 megabytes (2M x 32-bit) of software protected data storage.

Other early decisions included the use of a 400 bit/sec DPSK uplink and downlink for compatibility with the AMSAT community's existing command and telemetry hardware [9], CAN bus support, monitoring of the IHU on-board engineering beacon data stream, the use of programmable gate arrays to implement most of the hardware logic functions, and RAM-only memory system (no boot PROM).

Meetings

An on-going meeting has been held on the Internet since September 1997 and continues as of this writing.

The Design Review was held at the facilities of the Philipps University of Marburg, Germany, 1997 December 12-15. This was the only time the team was physically together. During these intense four days, the initial design was reviewed and substantially altered. It was at this meeting that the IQ modem was added, the single-wire expansion interface conceptually designed, and a FLASH memory chip included.

Hardware Development

The initial hardware design was accomplished during a three-week holiday in New Zealand! In fact, in order to meet the aggressive development schedule, this respite from normal work duties was necessary. The design was done on a laptop computer using the OrCAD Capture tools. Programmable logic was done on the same laptop using the QuickLogic tool chain [10.6] (and drew a lot of stares from other patrons at the downtown branch of the Christchurch Public Library!).

During the design process, the Internet proved to be invaluable in fetching the latest data sheets and specification of the parts to be used, and sorting through candidate parts in the search for the best available components.

Hardware Description

The block diagram, Figure 2, shows the overall hardware architecture of the IHU-2. The following narrative describes the function of each block in limited detail, and their interactions. Internet site references

for the principal ICs are given at the end of this paper.

The *Power Supply* operates from the spacecraft +10V bus. After combining, the merged +10V is run through a FET power switch under direct control of the Phase 3D IHU. When commanded on, independent switching power supplies provide the necessary +5V, +3.3V and +1.5V outputs needed by IHU-2. There is also a low duty-cycle +12V supply activated only when erasing and programming the FLASH memory.

The *CPU* consists of the SA-1100 chip and associated crystals. The part is so highly integrated that little else is needed.

The *Protected Memory* is composed of three (3) physical banks of 128K x 32-bit fast static RAM with error detection and correction (EDAC) logic implemented in a pair of QuickLogic field programmable gate arrays (FPGAs). A 2-out-of-3 majority vote system is employed, so that a bit may be corrupted in every memory bit location and the processor will still get accurate data. When an error is detected, the output from each memory bank is saved (96 bits total) as well as the address at which the error occurred. The processor may fetch this record for analysis or downlinking. In addition, the familiar 8-bit error counter is incremented, so that error rates as well as locations may be easily detected. Including correction delays, the memory system is designed for a nominal 70 ns access time.

Mass Memory consists of 8 megabytes of SRAM organized as 2M x 32-bit. This uses standard 4-megabit (512K x 8-bit) SRAM chips. Finally, there is a 128K x 8-bit Flash memory device using a 12-volt external power supply for erase and write. This type of memory was selected to avoid on-chip charge pumps, which are notoriously easily damaged by radiation.

Engineering Beacon data (for monitoring) passed from the IHU-1 is translated to 3.3V logic levels and passed into the FPGAs. Here, the sync vector is recognized, clock extracted, and differential decoding accomplished. The resulting data is presented to the CPU as 32-bit words, interrupt driven.

Uplink 400 bit/sec data is isolated by an op-amp, then sliced. The slicer output is fed into the FPGAs, where a digital phase-locked-loop (DPLL) recovers the clock. The recovered clock then operates an integrate-and-dump filter, and the output from this is passed back into the FPGAs for extraction of the data stream, differential decoding of the same, and block sync detection. A lock detector is also incorporated.

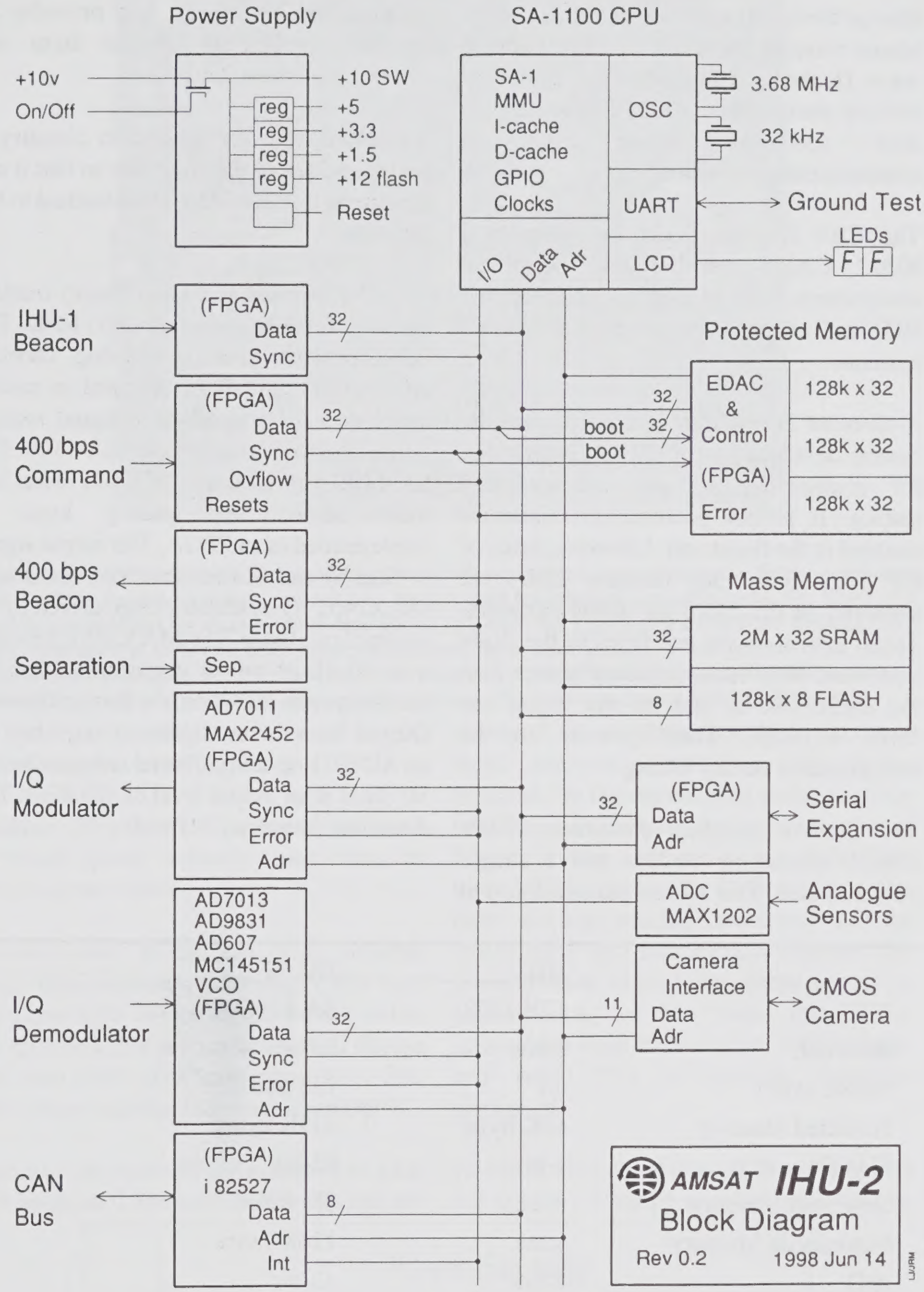


Figure 2. IHU-2 Block Diagram. Almost all *glue* logic is subsumed into three QuickLogic 2005 gate arrays, saving space and substantially reducing development time. Complex signal processing ICs are used as indicated. Most blocks are managed via interrupts (15 sources) marked Sync, Error, Ovflow and Int. The IHU-2 consumes just 1.2 watts at 10 volts.

If the unit has just been powered up or commanded to *reset and load* then the recovered data is passed through the FPGAs directly to the protected memory array. After the uploading of the requisite number of words, the CPU is given access to the memory and begins executing instructions. If the CPU is already running, the FPGAs then assemble each 32-bit word and interrupt the CPU so that it can fetch the word and process it.

Downlink 400 bit/sec data is presented to the FPGAs as 32 bit words. The FPGAs convert the data to serial format, differentially encode it, multiply it by the 400 Hz clock, and shift the data out. This data is then changed to 10-volt logic levels for use by Phase 3D. The FPGAs pace the data from the processor by means of interrupts. If data are not presented by the processor, the output of the uplink lock detector is used to

change the downlink from a nominal 400 Hz square wave (unlocked) to a 200 Hz square wave (locked). This helps the command stations assure that the IHU-2 has acquired their command signal prior to commencement of uploading.

The *CAN Interface* uses the same Intel 82527 CAN controller and peripheral components that are used in RUDAK, the IHU and other CAN-equipped Phase 3D systems.

A *Ground Serial Port*, modeled after the system developed for RUDAK, is provided for engineering unit development and testing. It is not powered or otherwise enabled in the flight unit. Likewise, a pair of HP 5082-7340 hex numeric LEDs are socketed on the board for debug purposes. These indicators are not fitted to the flight unit since they consume more power than the entire IHU-2, and no-one would see them anyway. They proved to be indispensable during testing.

The *Camera Interface* comprises 3V/5V CMOS translating buffers and a simple power switch. This allows the camera(s) to be switched on or off, and provides all needed signaling to control them and retrieve the image data.

An output from the Separation circuitry is scaled and fed to the processor so that it can determine if Phase 3D is still attached to the launcher.

An IQ (In-phase and Quadrature) modem operates at the spacecraft IF of 11 MHz. The IQ Downlink uses an Analog Devices AD7011 IQ modulator operated in analog mode and fed a quadrature signal sample under interrupt control by the SA-1100. The SA-1100 parallel bus to AD7011 serial bus transformation and pacing logic is implemented in an FPGA. The output signal is filtered and scaled, then presented to a MAX2452 IQ modulator chip, driven by an external oscillator. The MAX2452 provides over 40 dB of carrier suppression, and the whole system draws only a few milliwatts. Output from the modulator is amplified by an AD8031 op-amp, filtered and matched to 50 ohms at an output level of -20 dBm. The downlink frequency is fixed.

The *IQ Uplink* signal is presented to a 50 ohm matched load, filtered, and amplified by an AD607 IQ receiver chip. The IQ output is filtered and matched to an AD7013 IQ demodulator, whose samples are de-serialized and synchronized, then presented to the SA-1100 as 32-bit words, interrupt driven. A DAC output from the AD7013 is used to provide gain control for the AD607 under control of the SA-1100. The chip lineup used is designed for low power portable devices such as cell-phones and draws little power.

The local oscillator for the uplink needs to be variable and controlled by the SA-1100. The means to do this in a low power fashion is to use an AD9831 direct digital synthesizer (DDS) chip driving the reference input of an MC145151-2 PLL. A VCO made from discrete components is used as the variable oscillator. The SA-1100 can command the DDS chip over a wide range of frequencies with very good resolution. In this way, the SA-1100 can compensate for Doppler shift variations on the uplink as well as any other reasonable frequency drift, and close the loop for proper demodulation of the uplink signal using DSP techniques.

The IHU-2 includes an 8-channel, 12-bit *A/D Converter*. It is wired to monitor the +5, +3.3 and +1.5 volt power supplies as well as three temperature sensors (CPU, EDAC memory and unprotected memory). Additional inputs are provided to allow monitoring off-module parameters, none of which are currently defined for this mission.

Lastly, the one-wire *Serial Expansion Interface* is implemented in an FPGA with external level shifting. The external interface is designed as an open-collector of fairly low impedance to allow for a fairly fast transfer rate (4 μs/bit). Even with low impedance, because the duty cycle is very low, power dissipation is only a few milliwatts.

	IHU	IHU-2
CPU	CDP1802	SA-1100-AA
Buswidth	8 bits	32 bits
Native MIPS	0.1	133 max
Protected Memory	64K bytes	512K bytes
EDAC*	1-bit	32-bit
Unprotect Memory	none	8M bytes
Nonvolatile Memory	none	128K bytes
A/D	8-bit	12-bit
Expansion	Parallel	One-wire 32-bit serial
Command Uplink	400 bps DPSK	400 bps DPSK
Telemetry Downlink	400 bps DPSK	400 bps DPSK
Other Up/Down	None	IQ Modem 20 Kbps max
P3D CAN Bus	Yes	Yes
Engineering Beacon	Generates	Generates or Monitors Engineering Beacon
Size	200mm x 270mm	200mm x 270mm
Power	2-3 watts	1.5 watts
Technology	Static CMOS	Static CMOS
Rad Hard ICs	CPU, SRAM	None

* IHU EDAC can correct any single bit per 8-bit byte. IHU-2 EDAC can bit-wise correct a single bit error per bit location, or 32 bits per 32-bit word.

Table 1. A Comparision of the Old and New IHU-2 Systems.

Comparison with IHU

It is interesting to note that IHU-2 uses about half the number of ICs as the Phase 3D IHU, has 130 times the memory capacity, operates 1,500 times faster, uses the same physical PCB size (200mm x 270mm), and consumes half the power - 1.5 watts!

Table 1 compares and contrasts the old IHU and new IHU-2 system.

Hardware Development [N0ADI]

Electronic design matured over the period up to the end of January 1998. During this time it was reviewed and revised many times, until commitment to a PCB layout could be made (and time ran out).

The physical size of the PCB was fixed from the beginning. It would be a Phase 3D standard 200mm by 270mm board. We did have an option to use multiple PCBs if needed but this would have added significantly to the cost. It would have also required wires between the PCBs. Wires are undesirable. Space on the board was at a premium from the beginning. So here is how it was used.

Power supplies: 20 percent. There are five different voltages used by various ICs in the design. Four of them required on-board power supplies. This does not count the RS-232 voltages generated by the ground support serial port (not used on the flight unit). There are also filters on the supplied 10V.

EDAC memory: 20 percent. The EDAC memory scheme used requires the actual memory to be three times as large as the processor sees. This is necessary to allow a two-of-three vote for each bit. This scheme results in a much faster memory system than the Hamming 12 to 8 EDAC system used on previous designs, in order to support the much faster processor.

Unprotected memory: 20 percent. There are eight megabytes of memory here. Any data placed here will have to be protected by software EDAC.

Voltage level converters/buffers: 20 percent. Generally speaking, the lower voltage an IC is designed to operate at, the less power it will consume (it's a square law too). And power is obviously very important in any satellite design. Unfortunately, not all functions are available in low voltage ICs. And the satellite interfaces between modules are typically 10V. Therefore quite a few voltage level converters are needed. This isn't as big a hit on space as you might think since these voltage level converters also function as buffers which, in most cases, would have been needed anyway.

Connectors: 10 percent. There are six connectors, digital and analog, along a 200mm edge. There are also two additional connectors along a 270mm edge which are not used on the flight unit (such as the ground support serial port).

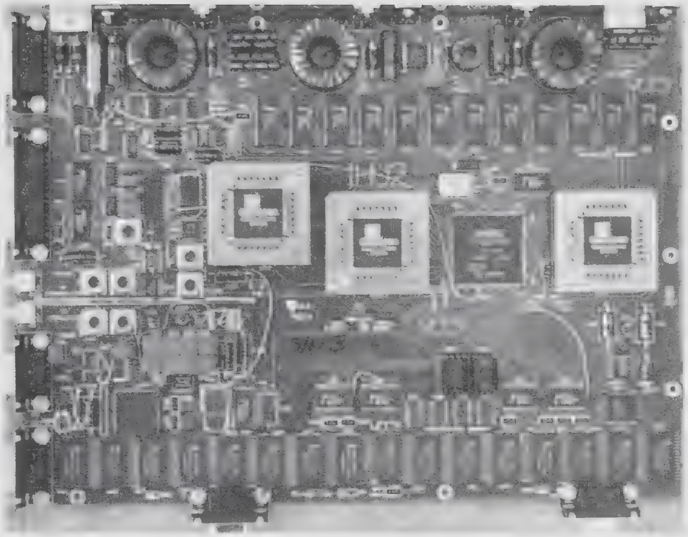


Figure 3. IHU-2 Photograph. Engineering model #3; six-layer board measures 270mm x 200mm. 341 surface mount resistors, capacitors, diodes, and transistors are underside. For flight, the board is surrounded by an aluminum frame/wall to which the connectors and PSU devices bolt. For thermal safety, CPU and both memory systems have heat shunts to the nearest wall. Lower connectors and LEDs are for test purposes only and do not fly, whilst the 3 FPGA daughter boards, presently socketed, are soldered down. The board is then conformally coated.

Modems: 20 percent. This board wouldn't be much good without some way to communicate with it.

Miscellaneous: 20 percent. This includes things like telemetry gathering, CAN bus, and a cute little device called the SA-1100. The CPU is a 208 pin surface mount device with lead pitch of 0.5mm, more than five times closer together than a standard DIP IC.

Similarly the three FPGAs have 144 pins with leads on 0.5mm pitch. The FPGAs are mounted on daughter boards to facilitate logic analyzer connection and device removal. On the engineering units, daughter boards are socketed. Due to the tight board layout, it was essential to pre-define the three FPGA pinouts for PCB routing. The rich on-chip routing resources of the QuickLogic anti-fuse FPGAs allowed this pre-definition with no significant impact on performance. In the end, the FPGA utilizations were 99% of pins, 75% of logic and only 25% of routing resources consumed.

As usual, the total of used PCB space comes out at 130%. Nothing new here, most of our

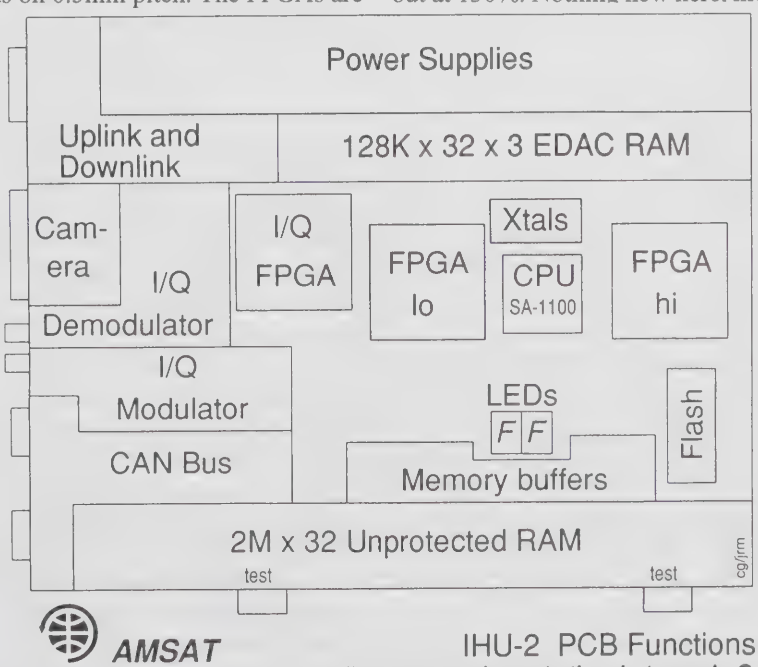


Figure 4. IHU-2 Functions Overlay. This diagram complements the photograph. Connectors from top-left are Spacecraft Interface, Camera Interface, I/Q Demodulator IF I/P, I/Q Modulator IF O/P, CAN bus in, CAN bus out, I/O expansion (single wire), and Ground Test serial port (RS232).

projects are like this. But somehow it always seems to fit.

The board is conservatively laid out using 10/9 rules (minimum trace width of 0.010 inches and minimum space between traces of 0.009 inches). The smallest drill size is 0.015 inch for vias. The board ended up being six layers (four signal, one ground and one power). The power plane was divided up to accommodate the various voltages used.

All of the ICs are surface mount devices. Most of the resistors, capacitors, diodes, and transistors are also surface mount. There are, however, quite a few thru-hole devices such as large capacitors, large diodes, inductors, voltage regulators and connectors. There are over 500 parts and almost 4000 soldered connections. The four PCBs (3 engineering, 1 flight) were entirely hand soldered.

A photograph of engineering model #3 is shown in Figure 3, and a key to functional placements is Figure 4.

IHU-2 device statistics:

Component	Surface-mount	Thru-hole
Capacitors	175	31
Resistors	149	4
Resistor packs	29	-
ICs	77	-
Transistors	13	3
Diodes	6	7
Inductors	4	13
Misc	-	8

3769 solder joints

519 electronic parts

```
;IHU-2's first test program.          Drive numeric LEDs at rate of 1/s
init        LDR    r12,PPC_base    ; get PPC Base address
            MOV    r0,#0xFF        ; set pins LDD[7-0] to be outputs
            STR    r0,[r12,#0]     ; write PPDR (Direction Register)
            MOV    r0,#0           ; start display counter at 0
main loop   STR    r0,[r12,#4]     ; write PPSR (LEDs)
            ADD    r0,r0,#1        ; increment display counter
            LDR    r1,count        ; initialise delay loop counter
Loop        SUBS   r1,r1,#1        ; decrement counter, setting flags
            BGT    loop            ; loop if r1>0
            B      main_loop       ; repeat forever

count       EQUD   248722          ; around about 1 sec?
PPC_base    EQUD   0x90060000      ; Pin Controller Base address
```

Figure 5. The first IHU-2 debug program. This one was written on Christmas Day 1997, 2-3 months before hardware existed. It worked first time. More demanding tests did not, and required regular software and hardware revision (coding and FPGAs), accomplished via the Internet. Later in the project (April 1998) the UK-AZ 8-hour time zone shift problem required a 5-day non-stop meeting in Tucson to complete the work efficiently.

Debugging the IHU-2 [G3RUH]

Bringing up a new computer from scratch is a fascinating experience. It begins with the application of power and literally checking for smoke (done Orlando, 1998 Mar 11). This is then followed by voltage measurements throughout. Essential services such as clocks are checked, and gradually static reasonableness checks are made to all sub-systems.

Next, since this is a spacecraft computer, one first investigates the command input hardware (uplink) bootloading system. Once this works, simple test programs can be uploaded.

The very first program is typically minimal; drive the numeric LEDs at a rate of one count/second timed by delay loop. That's hardly a dozen instructions, but a successful outcome implies the satisfactory functioning of a considerable amount of circuitry, FPGA logic and CPU set-up. See Figure 5. The IHU-2 ran this, its first program on 1998 Mar 27.

The next program does something similar, but uses the external 20 ms interrupt to do the 1 second timing. This verifies that we can handle simple interrupts properly. Since there are 15 possible interrupt sources in the IHU-2, this is a useful exercise to get right.

The IHU-2 *talks* to the ground station via a beacon, so the next stage is a program that will drive the downlink system, also by interrupts. Its output is shown in Figure 6. Data in the block is snatched from an SA-1100 3.68 MHz internal clock, and gives a clue to processor speed.

To conclude the I/O test phase, we check that there is input capability beyond the boot system. So the next test program is one that simply repeats any subsequent uplink straight back down on the beacon. This exercises two interrupt systems, and also requires circular buffer management to prevent input and output pointers from tripping over each other.

At this point we have verified that we have a computer system with the fundamentals, bootload, input and output functioning. In other words, a basically usable computer.

All subsequent work is checking that the CPU can communicate with the hardware sub-systems, and that those systems themselves work properly. In the order that we tested them; the unprotected 8 MB RAM, IHU-1 Engineering beacon monitor, I/Q modulator, I/Q demodulator, flash ROM read/write/erase, CAN bus, Camera interface, 1 wire serial interface, ground test UART. The memory EDAC system was checked by the simple expedient of omitting 1/3rd of the memory ICs (one bank) during PCB assembly. These ICs were installed later.

In all, some 40 programs were needed. Most of the systems worked immediately. A few did not, particularly the specialized ICs used in the I/Q mod/demod circuits. However, manufacturers' support was willingly given, and all systems were eventually brought up to specification.

Software Development

Writing the test software began as the railway train pulled out of Marburg after the December '97 review meeting, with a read-through of the amusingly entitled SA-1100 Data Sheet; this *sheet* is 350 pages long [4]. In keeping with the spirit of our project, actual coding started whilst on family vacation in Sweden over Christmas, using my host's computer. It continued for a month or so. Throughout all this, the

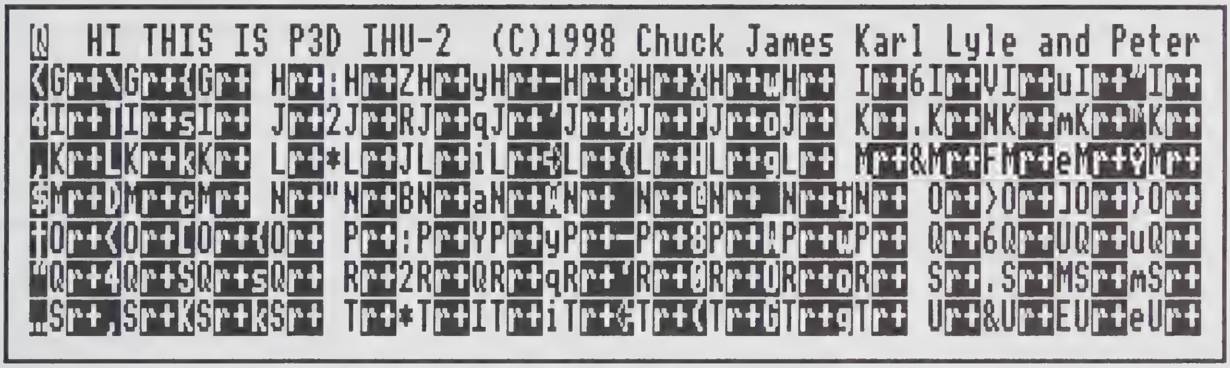


Figure 6. Downlink Screenshot.The first telemetry downlink block from IHU-2, 1998 Mar 29. The data was time snatched from the SA-1100 internal 3.684 MHz timer, giving an indication of instruction speed (0.6 MIPS at that moment). Telemetry aficionados will notice the downlink CRC error. This was traced to having forgotten to enable byte accesses to memory. This simple oversight was the cause of early debug frustration, and shows why trivial clues cannot be ignored.

IHU-2 existed only as drawings. Hardware appeared much later, in the middle of March 1998.

In addition to the test suite, two more important programs were written in this period. These were the Self-Checking Loader, and the AMSAT Phase 3 Operating System IPS.

Self-Checking Loader

A Self-Checking Loader is essential for loading long programs (i.e. longer than one boot block) into a spacecraft computer. This is because radio links are noisy, and therefore uplinked data sometimes gets corrupted. So, long programs have to be protected by a loader system that first checks itself for integrity, and then checks each target chunk on receipt at the spacecraft, requesting a re-transmission if errors are detected.

IPS Operating System

The AMSAT IPS operating system has been spectacularly successful in AO-10, AO-13 and AO-21's RUDAK system, as well as in a variety of early computers, notably the Atari 800 which was used for many years by Phase 3 command stations. This author (JRM) has ported IPS twice to run on the Acorn RISC Computer family. The first used BASIC to emulate a fictitious 64Kb computer called the M-9096. "C" would have been a better choice (for portability). The second port was written directly in assembler and is, unsurprisingly, about 100x faster. Its designation is IPS-M.

Acorn RISC Computers use ARM architecture processors, so the port of IPS to the IHU-2 was remarkably straightforward. It was simply stripped of all host computer specifics until just three *hooks* remained; 20ms interrupt, keyboard and screen. Conversion to the IHU-2 then only required substitution of these three elements by 20ms, uplink and downlink handlers of the IHU-2. When eventually uploaded to the IHU-2 (in late May 1998), IPS came up working immediately.

Once an OS is running, programs can then be written in the native high-level language, IPS itself. Many IPS programs and library sub-routines exist already and run without problems.

The version ported to IHU-2 is called IPS-EM, and is 16-bit oriented, reflecting its pedigree. Much of an IPS implementation is written in IPS itself, and a substantial proportion of IPS-EM high-level code is therefore identical to that of IPS-C/D (AO-13/P3D), both 16-bit environments.

The 32-bit version of IPS, called IPS-E, is presently being designed, and will be coded in the near future. It will be tested on an Acorn RISC Computer, and then ported to the IHU-2 in a manner similar to that described. IPS-EM is already blisteringly fast; IPS-E will improve on it by a factor of 2-3, as well as properly embracing the native ARM 32-bit architecture. This topic is dealt with by KM later in our paper.

About ARM Architecture

Many readers of this paper will be unfamiliar with ARM culture. The name originates from the *Acorn RISC Machine*, but is now owned and marketed by Advanced RISC Machines Ltd. The ARM RISC instruction set was devised by Sophie Wilson in 1983 and survives, extended but largely unscathed, to this day [2]. The ARM architecture is formally defined in reference [3].

The first processor using these principles, called ARM-1, was fabricated by VLSI in April 1985, and gave startling performance for the time, whilst using barely 25,000 transistors [1]. Building on that success, the ARM-2 was developed, and appeared first in a desktop computer in 1987, complete with a multi-tasking, mouse and window environment, drag n' drop, discless OS and much else. It was years ahead of its time, and whilst its prized successors continue in production, Acorn RISC Computers [Internet reference 10.2], along with many equally worthy platforms, have been eclipsed in popularity by global monopoly pressures in a largely naive marketplace.

ARM implementations continued to improve as microprocessor concepts and fabrication techniques advanced, finding wider application in high performance, low-power embedded systems. In 1990 ARM Ltd. was set up, with partners Apple

and VLSI with the mission "to be the global volume RISC standard in the emerging markets where computing, communications and consumer electronics converge."

This has certainly been achieved. ARM based processors are in fabrication by a large number of partners, using ARM-6/7/8/9 and SA-1 macrocells. See [10.1] for a long list that includes VLSI, GPS, TI, DEC, Sharp and Samsung.

The embedded processor market is a quiet revolution; but the chances are that you used an ARM processor within the last hour; perhaps in your cell-phone; maybe at a *hole-in-the-wall* cash dispenser linked by ISDN half way across the planet. Who knows? Who cares!

ARM-60 processors are aboard TMSAT, TiungSAT and UoSAT-12 as part of their GPS experiments.

The SA-1100 part adopted for the IHU-2 is an embodiment of the ARM architecture undertaken by Digital Equipment Corporation over the period 1995-7. Costing around $30 in quantity, it offers some 200 MIPS of performance for a fraction of a watt of power. The SA-1100 process has recently been transferred to Intel Corporation.

About RISC

RISC stands for Reduced Instruction Set Computer, an idea proposed by researchers at Stanford and Berkeley universities around 1980. As related to the ARM architecture it means:

- Fixed length instructions; 32-bits
- All instructions can be conditionally executed
- Lots of registers
- Data processing is register to register only
- 3 classes of instruction:

  - Data processing: 16 ADD SUB etc., 6 MULTS and a few processor internal management

  - Memory access: 6 Load/store register(s) to/from memory

  - Program flow: 2 Jump, jump subroutine

Other features of the programmer's model, dealt with fully in [3], support a range of interrupts, traps and supervisor calls, all grouped under the general heading of Exceptions.

The ARM handles I/O as memory-mapped devices with interrupt support. That is, devices such as discs, parallel and serial ports, etc. appear as addressable locations within the ARM's memory map.

To support rapid context switching in multi-processing environments, the mapping between virtual addresses generated by the processor, and the physical addresses wired to the memory chips is definable in chunks from 1Mb to as small as 1Kb. ARM architecture handles this through a Memory Management Unit (MMU). Also supported are instruction and/or data caches. MMU and caches are on-chip in the SA-1100; the instruction pipeline is 5 tier. See [2] page 329.

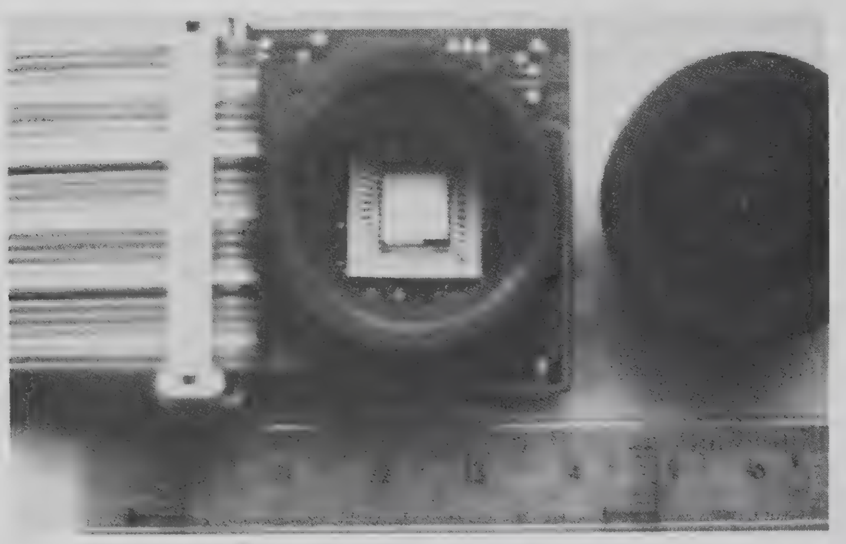


Figure 7. CMOS Camera. 512 x 512 imager shown in evaluation board configuration. From [10.3]

Development tools (hardware and software) are available for many platforms, including the IBM-PC under W3.1, W95 and W-NT, various Unix systems, and Acorn RISC Computers. These tools use C, C++, JAVA and Assembler.

Programming in ARM assembler is best described as exquisite.

ARM - Further Reading

Furber's ARM System Architecture [2] is an excellent discussion of the ARM design in particular, as well as contemporary microprocessor issues in general. Written by one of the original 1980's ARM-1 designers, now a professor researching (and making) asynchronous, i.e. unclocked, processors, this is the book for anyone interested in the subject at a serious level.

The ARM RISC Chip [1], also written by an ARM pioneer, takes a programmer's approach, and is weighted more toward the instruction set than the silicon. As does Furber, this book also contains fascinating historical material nowhere else recorded.

ARM Architecture Reference Manual [3] is the authoritative guide, and defines exactly what an ARM processor is. All ARM processors must conform to this text.

Data sheets for individual processors and core macrocells are available from their manufacturers, either on paper or via the Internet.

CMOS Camera [DB2OS]

The IHU-2 will have its own *eye*. Recently (1997) there have been interesting new developments in the area of camera and CCD chips. A new technology, the so-called CMOS APS (Active Pixel Sensors) can be very simply integrated into digital circuitry.

In contrast to the previous CCD sensors, these picture sensors can be read out like an EPROM. After applying an X and a Y address, the 8-bit value of the picture information is available for the selected pixel. The complicated timing and digitizing of picture data become totally unnecessary due to an on-chip flash Analog/Digital converter. There are no requirements regarding the readout speed as with normal CCD camera chips. Pixels can be randomly read in any fashion, i.e. the same pixel can be read at high speed or sub windows of the

pixel matrix can be accessed. The pixel address can be calculated *on the fly*.

This is indeed a very important advantage compared to the standard CCD sensors with the more complex timing. Pixels can be read by an interleaving scheme, and thus the raw image resolution will improve when more pixels are downloaded, etc. The maximum pixel rate of the CMOS Active Pixel Sensor is about 4 MHz. The user has full control over the number of pixels to read out and can exchange image resolution for frame rate.

In addition the CMOS APS exhibits superb picture characteristics, such as a very large logarithmic dynamic range of nearly 120 dB (6 light decades) in comparison to a normal CCD sensor with only 60 to 70 dB. The camera can see very bright and very dark parts in the same image. The well-known *blooming* effects of overloaded CCD sensors also disappear. Pixels are non-integrating; after being activated they measure throughput, not volume. A saturated pixel will never overflow and influence a neighbor pixel. The dark limit is typical 1 lux (0.001 possible) compared to 0.1 lux (.0001 possible) of a normal CCD sensor.

The camera used has a resolution of 512 x 512 pixels with an 8-bit resolution for the brightness information (black/white) [10.3]. The hardware effort is minimal, as is the interface to the IHU-2. The radiation hardness of CMOS APS sensors is exceptionally good at nearly 1 Mrad. Typical CCD sensors have a comparatively low radiation hardness of approximately 10 Krad.

The diameter of the earth is 16° at a distance of 47,000 km and 20° at a distance of 36,000 km. We decided to use a focal length of 17mm. With the optical sensitive area of 6.4mm x 6.4mm from our image sensor, this gives a Field of View (FOV) of about 21°. In comparison, the SCOPE cameras have a FOV of 16° for the Camera-A (narrow) and 32° for the Camera-B (wide). The precision optic for our camera is produced by Schneider Kreuznach. Because of the optical correction for the wavelength of 400 to 1000 nm, it gives very sharp images without focal difference for the whole visible spectrum to the near infrared. Further, no additional IR blocking filter is needed, which will also improve the overall sensitivity. The APS sensor has a large spectral response from 400 to 1050 nm and fits perfectly with the above optics.

Originally it was planned to mount two of these cameras on the satellite. One camera on the upper side and the other on the lower side. The idea was to film and thus document the separation of Phase 3D after launch. Comparably spectacular pictures have already been provided by TEAMSAT [10.4], launched with Ariane-502, which, as it turns out, employed the same camera technology.

Due to space limitations we decided to mount only a single camera on the upper side. Following separation it will still provide pictures of Earth. Later it can be used by IHU-2 as a navigation instrument in order to determine the spacecraft's orientation towards the Earth, and so enable attitude adjustment by the momentum wheels. It would be also possible to measure and track the daylight border line on the earth and re-orient the solar panels to the sun.

A subsequent job could be as star sensor for determining flight orientation, a task that the StrongARM SA-1100 could easily handle. The pictures from the camera will initially be stored in the 8 MB memory of the IHU-2. Without compression 32 pictures could be so stored. Appropriate JPEG compression would allow many more pictures, even a motion sequence to be stored. Pictures and motion sequences can be transmitted either through the IHU-2's own high speed DSP downlink or through the RUDAK experiment. In the second case, images will be transferred over the CAN network into the RUDAK Mailbox.

The CMOS APS camera is not intended to, nor can it, compete with the SCOPE experiment. It will be a technology demonstrator for future experiments.

AMSAT Phase 3 Flight Computers - Past, Present and Future [DJ4ZC]

Communication Constraints

The Phase 3-IHU was conceived in the mid-1970s as a concept to run a spacecraft autonomously without continuous ground intervention. After thinking through and analyzing this concept, it quickly became clear that project success would hinge on a sufficiently comfortable mode of programming and interacting with the computer.

An important limitation is the speed by which data can be transmitted between the satellite and the ground stations. The link performance, with distances up to 40,000 km, does not allow more than about 500 bit/s under worst-case conditions, and this only if better than the usual digital transmission techniques are used. For this reason, a format of 400 bit/s employing synchronous PSK was chosen [5].

Synchronous transmission formats are naturally block-oriented, so the adoption of PSK also suggested interacting with the computer in fixed length blocks - 512 byte blocks were chosen (with text this gives 8 lines with 64 characters).

In order to interact with the ground station computers, the same format was chosen. At the time this was a major departure from the *normal* way, because the typical computer of the time used character oriented teletype-like interfaces. Today it is normal to have a desktop with windows - but at the time the available video-units could barely support 16 lines by 64 characters.

Over the last 25 years the concept has proved its value, so there is no motivation to change it. It would be desirable to have higher interaction speeds with the spacecraft, but the link performance cannot be improved significantly. On the other hand the communication formats provide some margin by exploiting high-performance codes. This would in principle allow increasing the link-speed by a factor of 5 - 8. Presently we have provided a coded format for the uplink of the regular Phase 3D IHU, not to increase speed, but to have error tolerance in case of interference. With the IHU-2, the hardware allows experimenting with speed-increasing codes.

Program Performance and Interaction Constraints

Also early on it was recognized that the on-board computer would have to support many programs *running at the same time*. Thus a multiprogramming concept was necessary, and using today's parlance, a cooperative multitasking system was chosen. The system is in practice a single-user multi-tasking computer. In this environment a preemptive multitasking environment has more disadvantages than advantages; this was strikingly demonstrated by the nature of the problems encountered with the Sojourner-Rover on Mars (1997).

Furthermore, it was required that at any time it would be possible to interact with the program on all levels. Thus the language handler was made interactive; just another task running along with the other tasks.

For the programming language itself, Forth was found to provide a good starting point, because this language is nearly syntax-free and naturally extendible. In fact the application-programs differ in no way from the original language-constructs. A major advantage was the fact that the system is extremely small compared to any other language handler.

But it also soon became clear that Forth was in many ways too limited for our purposes. In particular:

- Its user interaction was teletype-oriented and not transparent enough.
- The language constructs were very rough and *human engineering* of the language had not really been a consideration in its design.
- The multitasking capability had to become an integral part of the language.

IPS - The Language of Phase 3 Spacecraft

With the above requirements, a language system was designed called IPS. Its basic structure is similar to Forth, i.e. a virtual 16-bit stack-computer emulated on the 8-bit processors of the time. For most control purposes 16-bit words are sufficient; for the few instances where 32-bit words were required, the language could be easily extended to provide the necessary operators for mathematical constructs. The language handler compiles addresses with two-level indirection. The resulting pseudocode allows very fast interpretation (emulation of the virtual 16-bit stack-machine). In addition, an interpretive mode is provided to allow interaction with the system - both programming and debugging. The language handler itself is written in IPS - thus the total system needs only about 8 Kbyte (correct, no mistake!) [6].

The interaction interface was designed from the start to use 512-byte blocks; thus many of the character-handling complications did not have to be addressed in the spacecraft. For the ground-station computers the same interface was adopted in various IPS-versions - early realizations of the windows concept.

The language itself was beta-tested at the University of Marburg, keeping track of the typical errors during programming. This allowed identification of those areas which were particularly error-prone. As a result the language IPS was *cleaned up* and a couple of changes were implemented before freezing the design. Just to mention a few: name-redefinition was prohibited, names of objects can have any length using a hashing technique to encode them (all characters significant). Also a number of compiler checks were added to catch the more common blunders. For this reason four distinct classes of code were created.

For multi-tasking a three-level approach was chosen. Routines of moderate time sensitivity can be placed into a *chain* - all the operators in the chain are executed in a round-robin fashion. It is the programmer's responsibility to make sure that no task grabs the processor excessively. Some special routines have been provided to relinquish and recapture control when waiting for external events.

Tasks requiring quicker service, say every 20ms, have a way of interrupting the high-level address interpreter (the so-called emulator pseudo-interrupt). Practically no overhead results from this approach when a stack-machine is interrupted. The interrupting routines can be either IPS or assembler. This approach guarantees the atomicity of IPS-instructions. The pseudo-interrupt turned out to be a very powerful concept and greatly helped to overcome the limitations resulting from the relatively small speed of the IHU.

For extremely time-critical tasks, real interrupt and even DMA is included in this concept.

IPS Performance on the IHU

We have now about 15 years of in orbit experience with the IHU and IPS. We have learned that the processing performance is quite adequate for the typical control tasks of a spacecraft using the COSMAC 8-bit processor running with a 1.6 MHz clock (0.1 MIPS of 8 bit). Also there have been no problems resulting from the attitude control and orbital mechanics mathematical requirements which need to be performed in real time. But complex communications code-processing or real time image handling (e.g. as sensor complements) are beyond the capability of the old IHU.

An unexpected side effect of the IPS stack architecture is the property of the language to turn most programming mistakes into errors resulting in the wrong number of items on the stack. This is immediately visible and thus allows error detection very early on. Thus IPS-programs, once they run, probably have less hidden errors than programs written in syntax controlled languages. The net effect of this is that IPS has turned out to be a very useful tool to create ultra-reliable programs - for satellites definitely a welcome bonus.

IPS-32 for the IHU-2

With the IHU-2 we have jumped immediately from 8-bit machines to 32-bit machines. But IPS was only intended to emulate a virtual 16 bit machine. Thus the hardware has overtaken the software, and to continue with a 16-bit IPS would unnecessarily tie down the performance of the new IHU-2; it takes more overhead (2-3x more) to emulate the 16 bit architecture of IPS than just passing through the 32-bit performance of the StrongARM.

Fortunately to redefine the word-structure to be 32-bit does not significantly impact the language itself. In fact most programs would run without any changes. Only programs which explicitly exploit the wrap-around properties of 16-bit words (like our angle representation used in the spacecraft) would need some modifications.

Basically the implementation also becomes simpler using the 32-bit words of the processor for the kernel-primitives. But there is a down-side; because now the addresses compiled by the system are 32 bit instead of 16 bit, the memory requirement about doubles. In practice, this is no problem, because during the last 25 years, computer memories have increased about 1000-fold. So a factor of two can easily be absorbed today - the system will be about 16 Kbyte large. Also this allows eliminating some of the specialized memory saving constructs of the old IPS (like 1 byte literals), making the system simpler.

The only remaining obstacle at this time (May 1998) is that a different pseudo-code structure needs a new compiler. Previous versions of IPS have been compiled using a special meta-compiler (IPS-X) which creates the specific 16-bit pseudo code.

Using this tool, the first 16-bit IPS for the IHU-2 (IPS-EM) was created [7].

For IPS-32, the meta-compiler must first be modified in order to compile the new target pseudo-code. All other tools have been built during the last 12 months on Acorn StrongARM RiscPCs, in particular an assembler for the StrongARM, written in IPS [8].

So it is probably only a matter of a fairly short time until IPS-32 becomes available for both the IHU-2 and the RiscPC. Then the about 5000-times larger power of the StrongARM will be available from the very convenient IPS interface giving us unprecedented processing power to explore new software communication technologies both for space and for the ground-segment.

The Players and Acknowledgements [WA7GXD]

The project leader is Lyle Johnson, WA7GXD. He also did most of the hardware and logic design, and some debugging of code.

Chuck Green, N0ADI, did the PCB layout and constructed all engineering and flight units, as well as participated in the debugging process.

James Miller, G3RUH, ported the IPS operating system to the ARM and the IHU-2, wrote the vast amount of debugging code, assisted in the debug process in sunny Tucson and edited this manuscript.

Karl Meinzer, DJ4ZC, provided much of the stimulus for the project, embarked on the design of IPS-32, held out for the single-wire serial interface and IQ modem functions of the system, as well as hosted the design review less than two weeks before Christmas.

Peter Gülzow, DB2OS, initiated the discussions that launched the project, found the camera technology and researched and located much of the information needed in the early design discussions. Peter's more general IHU-2 article, suitable for magazines, is available from [Internet reference 10.15].

All the players participated in the intense design review meeting, evaluation and critiques of the evolving design.

Others who have made technical and logistic contributions include, with thanks, Werner Haas DJ5KQ (AMSAT-DL), Matjaz Vidmar S53MV (high speed data), Larry Brown NW7N (tantalum IC shields), Dick Jansson WD4FAB (heatsink metalwork), MMSI Tucson (test equipment), Stacey Mills W4SM (proofreading) and our families (understanding). Personnel may be contacted via callsign@amsat.org

AMSAT-DL agreed to fund the project, which almost immediately exceeded budget.

References

1. The ARM RISC Chip, A. van Someren and C. Atack, Addison Wesley 1994. ISBN 0-201-62410-9.

2. ARM System Architecture, S. Furber, Addison-Wesley 1996. ISBN 0-201-40352-8.

3. *ARM Architecture Reference Manual*, Prentice Hall 1996. ISBN 0-13-736299-4.

4. StrongARM SA-1100 Data Sheet V2.2, Digital Equipment Corporation 1997, V3.0 Intel Corporation 1998.

5. *Die digitale Nachrichtentechnik der AMSAT-Phase-III-Satelliten*, K. Meinzer, CQ-DL, 10/1978, pp. 447-453 AMSAT Phase III Satellite Digital Communication Techniques.

6. *IPS - High Level Programming of Small Systems*, K. Meinzer, 1978, 2nd Edition. Publ. by J. Miller 1997 ISBN 0-9530507-0-X. For availability see [10.13].

7. IPS-EM and IHU-2 Debug tools, continuously updated for IHU-2 group. James Miller.

8. *Assembler for the Arm, Version T.2 for IPS-M*, Karl Meinzer, 2.11.1997, IHU-2 group document.

9. Phase 3 400 bps PSK Data Demodulator MK II. *OSCAR News*, 1992 Dec, No.98 p39. PCB available; see [10.14].■

10. Internet References

1. ARM Ltd.	http://www.arm.com/
2. Acorn RiscPC	http://www.acorn.com/acorn/products/strongarm/
3. CMOS Camera	http://www.imec.be/fuga/fuga/datasheets.html
4. TEAMSAT photos	http://www.imec.be/fuga/cmos/vts.html
5. SA-1100	http://developer.intel.com/design/strong/
6. FPGAs	http://www.quicklogic.com/products/pasic2/ql2005.pdf
7. AD7013	http://www.analog.com/pdf/ad7013.pdf
8. AD607	http://www.analog.com/pdf/1824_0.pdf
9. AD9831	http://www.analog.com/pdf/ad9831.pdf
10. MC145151	http://mot2.indirect.com/books/dl110/pdf/mc145151-2rev2-1.pdf
11. Max2452	http://209.1.238.250/arpdf/1240.pdf
12. AD7011	http://www.analog.com/pdf/ad7011.pdf
13. IPS Book	http://www.jrmiller.demon.co.uk/products/ipsbk.html
14. P3 Demod PCB	http://www.jrmiller.demon.co.uk/products/p3dem.html
15. IHU-2 Article	http://www.aball.de/~pg/amsat/yahue.html (in English)

Broadband Log Periodic Antenna: 130–1300 MHz

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Translated by Laura Halliday VA3LDH

The logarithmic antenna—or *log-periodic*—is routinely used in professional circles for radio spectrum monitoring, for civilian and military communications, even for radio astronomy. Its large bandwidth is its main asset. The description that follows has the goal of shedding a little light on this antenna type which is little known in the amateur world.

Why such an antenna? Its purpose is to offer a broad passband, with gain at all frequencies.

A single logarithmic antenna fed by a single coaxial cable permits coverage of several octaves, without any gaps. The parameters that characterize it (impedance, radiation pattern, front-to-back ratio) vary little over the covered frequency range.

What does it look like? A boom, supporting radiating elements (Figure 1). Its shape, weight and bulk are similar to a Yagi antenna, though its function and behavior are different.

Why isn't this antenna more widespread in amateur circles? Perhaps because, for an equal size, it has less gain than a Yagi. However it is hardly more difficult to build, and its usage is fully justified when looking for a simple and economical installation that permits:

- Multiband operation on 2m, 70cm and 23cm, and reception of the entire surrounding spectrum (as countires other than France have access to these bands).
- Satellite operation (except for serious DX), thanks to its large main lobe and its VHF/UHF capability.

From theory…

- The log-periodic antenna (LPDA, *L*og *P*eriodic *D*ipole *A*rray) consists of a series of radiating dipoles fed 180 degrees out of phase.
- The length of the dipoles, as well as the distance between them, increases from one end of the antenna to the other.
- The secret of the log-periodic antenna resides in the fact that the ratio of the lengths of two consecutive dipoles is

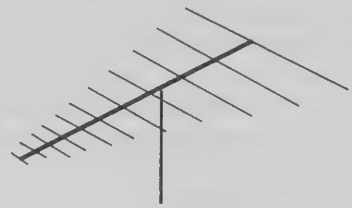

Figure 1. A Log-Periodic Antenna

equal to the ratio of the distance between them. This ratio is constant for a particular antenna.
- Thus, for any frequency within the passband, the transmitter or receiver connected to the antenna sees the same type of structure (Figure 2), namely:
  - A resonant dipole (or nearly so)
  - Shorter dipoles as directors
  - Longer dipoles as reflectors

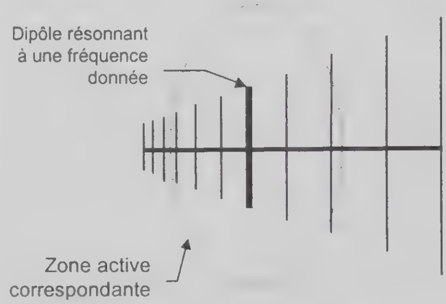

Figure 2. *Dipôle résonnant à une fréquence donnée* = Dipole resonant at a given frequency; *Zone active correspondante* = Corresponding active zone

For the highest frequency there are no more directors; for the lowest, no more reflectors. Only the dipoles close to resonance contribute effectively to the functioning of the antenna. This explains why the gain of a log-periodic antenna is lower than that of a Yagi with the same number of elements. It can be seen that the active area of the antenna and its phase center move as a function of the frequency of operation.

Since the distances between elements and their lengths form a geometric progression, one can see that the antenna keeps its characteristics (impedance, gain, pattern, etc.) stable and independent of the frequency.

The basic equations for the antenna are as follows:

$$\tau = L_2/L_1 = L_3/L_2 = L_n/L_{n-1}$$

$$\tau = D_{32}/D_{21} = D_{43}/D_{32} = D_{n,n-1}/D_{n-1,n-2}$$

$$\sigma = D_{n,n-1}/2\ L_{n-1}$$

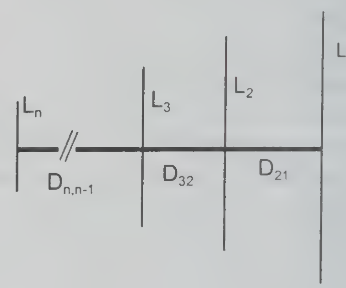

Figure 3. Log-Periodic Antenna Dimensions

Hams who are interested in the details of the calculations will find it useful to refer to the *ARRL Antenna Book* (published by the American Radio Relay League), or to the *Antenna Engineering Handbook*, by H. Jasik (McGraw-Hill).

Two programs were used to rapidly design this antenna. The first, LPCAD, is a program that runs under DOS. Developed by WB0DGF, it is dedicated to the design of log-periodic antennas and makes it possible to very easily calculate and optimize all the dimensions of the antenna.

The second, NEC4WIN, is a Windows program. Created by VE2GMI from the Naval Ocean Systems Center in San Diego's. MININEC code, it permits a very complete simulation of all kinds of antennas (beams, quads, verticals, Yagis, etc.

Armed with these two programs nothing will stop you from calculating a log-periodic antenna covering for example, 7 to 28 MHz (you'll need a *big* back yard), or 144 to 146 MHz, or even 130 to 1300 MHz, as in this article.

…to practice

Remember that each dipole is fed 180 degrees out of phase from its neighbors. For construction, the trick is to design a simple and robust approach to feeding the dipoles The traditional crossed wire line used for HF log

periodic antennas (see Figure 4) is not suited to the high frequencies that concern us here.

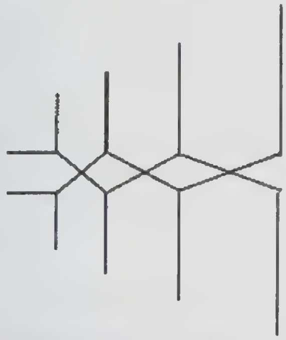

Figure 4. Traditional Feed for HF Log-Periodic Antennas

The solution is to use two parallel rectangular booms, one on top of the other (see Figures 5, 7 and 8).

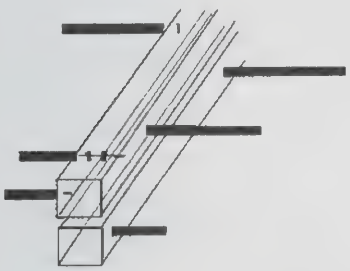

Figure 5. Combined Feed and Boom Arrangement for a VHF/UHF Log-Periodic Antenna

For a better understanding, Figure 6 shows the antenna as seen from above. The +++ symbols represent all the half-dipoles attached to the upper boom, and the —- symbols represent the other half-dipoles connected to the lower boom.

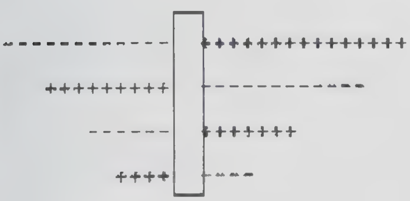

Figure 6. Elements Fed Out of Phase

With this sign convention the successive phase inversions are easily seen.

Let's now move to practical details.

For a 23 element antenna mounted on 2.05m booms, intended to operate between 130 and 1300 MHz, Table 1 provides the necessary numbers, in millimeters.

The left column is the position of the dipole (from the largest to the smallest). The following column gives the successive spacing between dipoles. This is then followed by the length of each dipole.

The last column gives the length of each element. Note that the length of each element is slightly shorter than the corresponding half-dipole: since it is necessary to compensate for the size of the boom. The largest dipole is 25 mm from the end of the booms.

The boom consists of two lengths of 30 mm square aluminum tubing, 12 mm apart.

Element Number	Distance	Dipole Length	Element Length
1	0	1177	583.5
2	238	1047	518.5
3	212	932	461
4	189	829	409.5
5	168	738	364
6	152	657	323.5
7	133	585	287.5
8	118	520	255
9	105	463	226.5
10	94	412	201
11	83	367	178.5
12	74	326	158
13	66	290	140
14	59	258	124
15	52	230	110
16	47	205	97.5
17	41	182	86
18	37	162	76
19	33	144	67
20	29	128	59
21	26	114	52
22	23	102	46
23	21	91	40.5

Table 1. Measurement in millimeters for 23 element 130 to 1300 MHz Log-Periodic Antenna.

The spacing between the two lengths of tubing is maintained by four pairs of insulating plates attached to the sides at regular intervals.

The elements are attached by nuts on the sides of the tubing (see Figure 7).

Each element consists of a length of 8 mm diameter aluminum rod, threaded for 20 mm at one end. The threads allow for precise adjustment of the length of each element.

A locknut on each rod permits locking it in place after fine adjustments.

You will need a total of 9.96 m of 8 mm aluminum rod to make the 46 elements. Allowing for the inevitable mistakes and

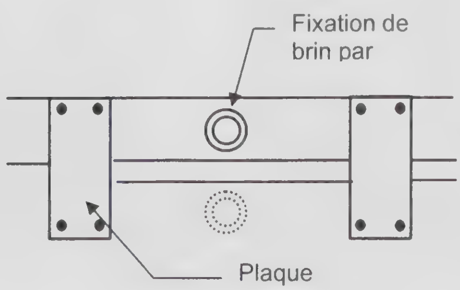

Figure 7. ***Fixation de brin par écrou serti*** **= Element attachment by lock nut;** ***Plaque isolante*** **= insulating plate.**

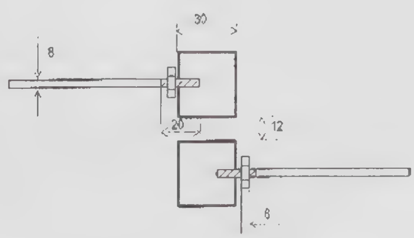

Figure 8. Mounting Dimensions in Millimeters

wastage, it is prudent to have at least 11 m available. Your supplies and available tools may suggest other ways of attaching the elements. The essential criterion is to guarantee an excellent, durable electrical contact.

The final step is the connection to the antenna.

This is achieved by an N connector mounted adjacent to element 23 (i.e. the shortest). The connector body (ground) is connected to the lower boom, with the central connector connected to the upper boom.

The coax feed is fixed to the lower boom with the help of plastic collars. The connection can then be weather-proofed with self-amalgamating tape.

The attachment of the antenna to the mast is made by the lower boom. Being at ground potential, it can be directly attached to a metallic mast by the usual U bolt clamp commonly used for television antennas. Make sure that the *upper* boom does not touch the mast!

Electrical Characteristics

The main theoretical parameters are as follows:

Passband	130 to 1300 MHz
Input impedance	≅42 Ω
SWR	≤2
Gain	>7 dBi
Front to back ratio	13 to 19 dB

The attached plots are the azimuth and elevation radiation patterns of the antenna, simulated by NEC4WIN, at 435 MHz in free space.

Required Materials

- 11 m of 8 mm diameter aluminum rod
- 4.1 m of 30 mm square aluminum tubing
- 46 8 mm lock nuts
- 46 8 mm nuts
- 1 roll self-amalgamating tape
- 1 TV antenna U clamp
- die to thread the elements
- 1 female N connector
- Insulation material (Plexiglas, epoxy PC board, etc.)
- Sufficient patience to make the 46 elements

Most of the above items (except for the last three) are easily found in do-it-yourself superstores.

Usage

The antenna is regularly used at the station for local and satellite communication. Due to a lack of equipment, 23cm has not been tested. Despite an unfavorable location (the Orge Valley), the antenna is regularly used for satellite communication with AO-10, RS-12/13, RS15, FO20 and FO29 down to elevations of less than 40 degrees.

Its very large passband makes it an interesting antenna for listening to VHF/UHF communications.

A single gain antenna, a single coaxial cable for more than 1000 MHz of bandwidth, how could you do better?

Jean-Louis Rault, F6AGR

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FRANCE

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NATSweb Sat: We Almost Made It!

Bob Bruninga, WB4APR, *wb4apr@amsat.org*

NATSweb was conceived, designed and constructed in less than six weeks and almost made it to orbit! Given notice of a possible launch opportunity the week before Christmas, teams at the U.S. Naval Academy and Weber State University worked through the holidays to prepare a viable satellite payload for delivery to the launcher by the first week of February 1999. The launch opportunity was as an attached payload to an upperstage geostationary transfer vehicle resulting in an orbit on the equator at 36,000 km apogee by 660 km perogee that would give 12-hour a day coverage to anyone on Earth (except the poles).

The desired Amateur Radio mission was to provide an APRS mobile position and status reporting link from mobiles anywhere back into the worldwide APRS infrastructure. But to provide this mobile-to-satellite coverage, there were three significant challenges:

- The spacecraft had no attitude control which as a result, demanded the use of omni directional antennas.
- The satellite would be near apogee most of the time with a path length to the mobiles of over 30,000 km.
- There were no 2 meter Amateur Radio satellite frequencies available for use as well as no time for formal Amateur Radio satellite frequency request and coordination.

The first two limitations forced the requirement for 2 meter operations which lead to the third problem of the lack of such frequencies in the 2 meter satellite band. The link requirements are 9 dB easier to meet on 2 meters than on 70 cm and make the application possible. On 70 cm, a 2 kW mobile transmitter would have been needed.

Frequency

To resolve the frequency problem, we had proposed the use of the existing 144.39 MHz North American continent APRS frequency for operations over the western hemisphere. Although this frequency is in use by thousands of existing APRS users, this unique application could not only share the frequency as a mobile uplink, but also as a downlink frequency. This was possible because the mobiles would transmit their energy *up* to the satellite while all the terrestrial users focus their transmitted energy on the horizon. Thus it is easy to achieve 10 to 13 dB isolation between the two sets of users. Since the downlink is only used to feed all position/status reports into the worldwide linked APRServe Internet system, multiple receive sites would guarantee that at least one site received every packet. Thus the frequency problem was solved!

But this solution only works in North America where 144.39 MHz is dedicated to mobile APRS operations continent wide. For this reason, a dual redundant system was also included on the spacecraft for use when APRS eventually catches on in Regions 1 and 3. This frequency could be activated later on whatever frequency eventually becomes the APRS channel in Europe.

Spacecraft Communication Payload

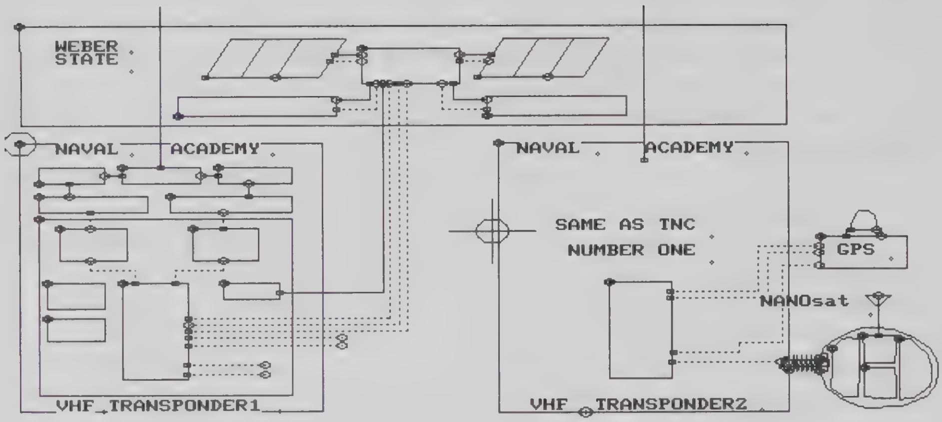
The communications payload consisted of two completely separate but identical KPC-3+ TNC's and 2 meter radios. One was on a vertical whip antenna and the other on a horizontal whip antenna. Transmitter power out was a whopping 10 watts each! Each digipeater was backed up with a fail-safe timer circuit that would power-cycle the TNC's if there was no PTT activity in over a minute. Kantronics had burned us a pair of ROMS with our defaults, so we came up ready to go after each power cycle. We also added a special tone reset circuit as an added precaution.

Power System and Structure

Each system had its own battery and six solar panels for nearly 100 percent sun illumination. One of the TNC remote control lines on each TNC was used to cross connect the power systems in case one system failed; then we could use its battery for the other one. Dr. Bill Clapp at Weber State University in Ogden Utah was doing the power systems, and we at the U.S. Naval Academy were doing the

NATSweb undergoing Antenna SWR measurements at 145 MHz. Using 1 inch steel tape antenna, 18" long. SWR of 1.0:1 was achieved.

NATsat transmitter and PA module (underneath) mounted on the bottom of the KPC-3 chassis. In the forground is the telemetry module and all the interface wiring. The empty space in the left foreground is for the receiver.



NATsat block diagram.

communication package. We would attach to a 9 foot by 3 foot square open box truss made out of 3000 lbs of steel built by Boeing as their dummy mass. This mass was a vibration mass test unit never intended for launch, but since there were no other payloads, it became the prime payload. Unfortunately for us, it was painted all WHITE, so its average temperature would be a very cold -60° C. We were using a thermal insulator and then thermal coatings on our boxes to achieve a nice 0° to 30° C operating temperature for us. This thermal design was a non-trivial exercise!

Telemetry

We used the LEDS ON/OFF switch in the TNC to switch the five available analog inputs to two banks of sensors, four currents, four temperatures, battery voltage and RF power out for each system. Thus a total of 20 telemetry values from our off-the-shelf KPC-3+'s! (This satellite has no other command/control system other than the TNC's).

Link Budget

Any APRS user could hit the digipeaters with a 160W mobile amp and a mobile antenna (optimized for peak power up at an angle of about 40° as 36,000 km is a long way away). Anyone could hear the downlink with an OSCAR-10 class station. But the intent was to just have a half dozen permanent ground stations feed the downlink into the APRServe network. Thus, everyone everywhere could see all satellite mobiles via the existing APRS worldwide infrastructure.

Uplink

One uplink was on 144.39 MHz since it was already authorized over the entire North American continent. Since target mobiles would be radiating mostly upward and all other terrestrial users would be radiating on their horizons, we calculated we could get a 10 to 16 dB SNR so that the mobiles would be heard above all other users. (The second system was for a possible alternate uplink in the amateur satellite segment in case APRS caught on in Europe as 144.39 MHz is a weak signal frequency.)

Downlink

We could also downlink on 144.39 MHz just fine, since with six ground stations monitoring 24-hours a day and feeding their combined signal into APRServe. The chance that all six stations would have local QRM at any instant is 0.01 percent. This gave us a 99.99 percent probability of success on every packet. Our signal from 36,000 km would be so weak to all other APRS users, they would not even be able to hear it except with a beam antenna pointed *up*...thus we could operate fully on 144.39 MHz.

But alas, the U.S. Department of State has recently become involved in the very tedious Technology Export Licensing business that now includes all U.S. satellites being launched on another country rockets! Our *free* ride was on the launch of a totally passive dummy 3,000 lb *mass* being launched to test the Boeing Company's *Sea Launch* system. Since the launch will be in international waters, using a Russian rocket, on a Scandinavian ship with system integration by Boeing, Boeing had to get a Technology Export License from the State Department for the Launch. (This process takes months if not years!) Now, since Boeing was going to add us (an active payload) to their dummy mass, the State Department said this was "a change to Boeing's export license which would have to be modified and resubmitted."

This was unfortunate as some engineers at Boeing were actually getting excited about our system, since it would give them attitude and temperature information which they had no other means for getting from their totally passive mass. Integration of our NATSweb satellite was on their work plan for integration and they had had engineers working with us in preparation for the clean room integration for the last month.

Boeing had been fighting for us throughout January 1999 trying to convince the State Department that this was a trivial change to their Export License and that it did not need this kind of bureaucratic oversight. However with their launch on line and only weeks away, they could not take the risk of resubmitting their paperwork (which has been the subject of lots of State Department oversight of late) just for our $2000 attachment. So on a Friday afternoon, only two days before spacecraft/launcher integration, we were bumped from the launch. Boeing's 3000 chunk of steel goes to orbit (for hundreds of years) with no telemetry system at all.

But we *do* now have a satellite *ready to go* for the next opportunity! (Anyone know of another free launch?)

Oh yes, our NATSweb satellite also had a NASA modified GPS unit attached to one of the TNC's so that we could see how well GPS worked from space!

Editors's Note: For details on the design of NATSweb, see WB4APR's web page: http://web.usna.navy.mil/~bruninga/natsat.html ■

Solar Spectrum Calculations and Phase 3D Sun Sensor Calibration

Gerd Schrick, WB8IFM (Phase 3D Team)

Two previous articles (1, 2) have described the location and calibration of the sun sensors on Phase 3D. The proper design of the sun sensor attitude system requires knowledge of the spectral distribution of the sun's energy. This article provides some background on this topic and additional calibration data on the Phase 3D sun sensors and expected solar panel power.

The Solar spectrum, Figure 1, looks somewhat like the output curve of a transmitter plotted versus wavelength. However, there is a difference; the transmitter curve shows the output power we get at a particular wavelength vs. wavelength (or frequency), while the solar spectrum indicates power that is transmitted at all the wavelengths simultaneously. In fact, the labeling of the abscissa in watts per wavelength points to that. In Optics it is customary to use wavelength rather than frequency; of course they are interchangeable.

The shape of the spectrum is very close to a *blackbody* curve. The sun can essentially be described as a **blackbody radiator at 6000 K**. The graph (dashed line in Figure 1) includes the blackbody curve for 5900 K. At a recent presentation about radio astronomy, Ed Kulesa, K2VEE, related that one aspect of blackbody curves is, that they do not overlap, i.e. the temperature completely describes the curve. We are extremely lucky to have the sun as a blackbody and not some other type of radiator. At 6000 K the main output of the sun is in the "visible" part of the electromagnetic spectrum. Indeed; one could say: 'what you see is what you get'. This leaves the *radio spectrum*, which is much lower in frequency, with only a small fraction of solar power. However, even this small part is enough to in some cases blot out weak microwave signals if the antennas are aimed at the sun. Even on 10 m you can pick up sun noise by pointing your beam west into the sunset.

Nature has designed our eyes (receiver) to peak in the same range as the sun. So the sun provides, besides the heat that warms up the earth to a comfortable temperature, also the perfect illumination during the day. Even the solar reflection from the moon is enough so that 100 years ago, when city night illumination just started and was expensive, one week per month around the full moon the streetlights were turned off.

Figure 1 shows two solar spectra; one valid at sea level and the other as seen in space. The sea level spectrum shows power dips at a number of selected wavelengths. This is caused by absorption of the sun's rays by gases (water vapor and oxygen) in the Earth's atmosphere and gets severe when the sun is close to the horizon where the path length is longest. Beautiful, mostly red-colored sunsets are the result. Only with a lot of attenuation, such as at sunset through a thin cloud layer, can you actually look at the sun. Last summer we watched a sunset like this at Lake Erie and observed a huge sunspot in the upper left corner and two small ones towards the center. Also we could distinctly make out the sun as a sphere, rather than a disk, as it normally appears.

The atmospheric influence makes it difficult to obtain good readings of the solar output on the ground. Looking straight at the sun around noontime in Orlando we measured 1.5 mA with one of the Phase 3D silicon photocells (Hamamatsu SK1226 BK) in early March and only 1 mA in early July. The drop in the reading was caused most likely by the more humid air and possibly smoke from the Florida fires.

Let's calculate the total power density of the sun as received in space. Taking data from a Figure 1 at 0.1μ intervals we come up with column 2 in Table 1. As an example: at 0.5 μ wavelength the power density reads .28 mW/cm^2 x 0.1μ. We choose a range of wavelengths from 0.4μ to 1μ, which includes part of the near infrared. In order to get the total power density we have to add these power chunks, performing what is mathematically known as an integration. This simple calculation gives us 131.3 mW/cm^2. This value compares favorably to the recorded **medium solar constant of 1390 W/m^2** (=139mW/cm^2), which is slightly larger as it contains data beyond our selected wavelength range. This gives us confidence to proceed with the calculations to check the response of the Phase 3D solar sensors.

This power density obtained is for a receiver (photocell) with a flat pass band. It is what we are accustomed to in our radios. However, the photocell sensors that do the sun tracking, have a changing sensitivity with frequency (Figure 2), which we take into account in column 4 of Table 1. Column 3 figures the power impinging on the 5.5mm^2 area of the photocell. Adding up the final (5th) column gives us the 1.94 mA of photo current, which we will expect to encounter in space. This compares to the 1.5 and. 1.0 mA we measured in March and July

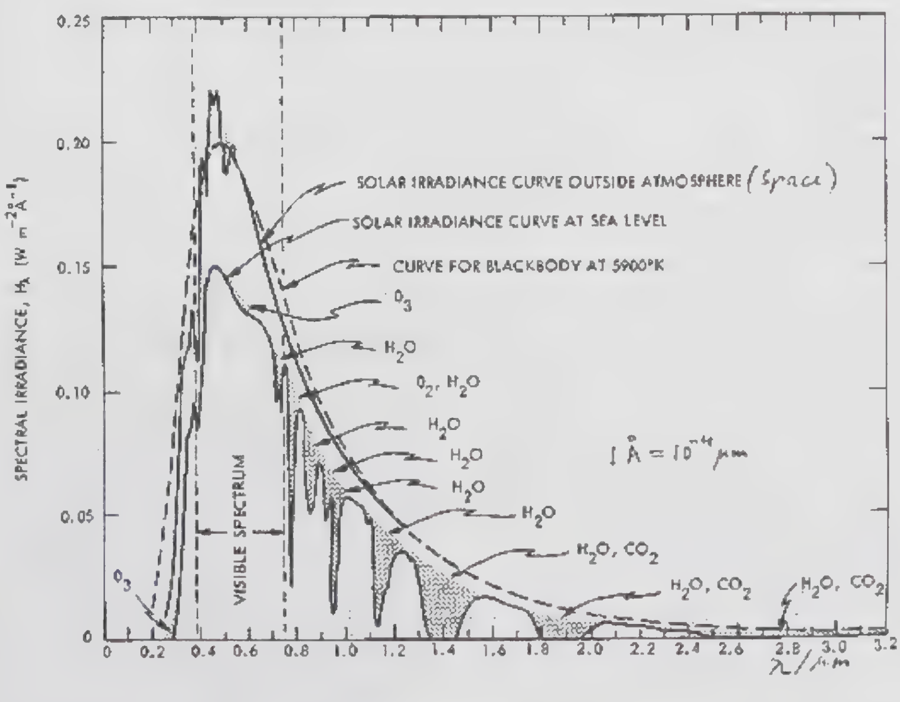


Figure 1. Solar Power Density. 1Å = `10-4 μm

at the Phase 3D Integration Laboratory in Orlando, FL

Now we can with confidence set the sensitivity of all 16 of the various Phase 3D sun sensors. To make sure we do not saturate any of them, we stay 10 percent below the maximum reading at full illumination.

It is interesting to use the solar constant to estimate the power received by the solar panels of P3D. There are 4 panels of 105.3 cm x 62.8 cm and 2 panels of 105.3 cm x 56.5 cm for a combined area of **3.3 m (35.5 sq ft)**. So we receive 4.6 kW of solar power. Converting 12 percent of this into electricity we have **550 Watts** available from the sun, with perfect alignment, of course.

References

1. "Phase 3D is Getting Ready to Fly" by Gerd Schrick, *The AMSAT Journal*, May/June 1998, page 9.

2. "Sun Sensors on Phase 3D" by Gerd Schrick, *The AMSAT Journal*, July/August 1998, page 12. ■

Wavelength (μ)	Solar Spectrum Power Density (mW/cm^2·0.1μ)	mW at Photocell (5.7mm^2)	Photocell Response (mA/mW)	Photocell Output (mA)
0.4	31.3	1.78	0.175	0.31
0.5	28.3	1.61	0.26	0.42
0.6	22.5	1.28	0.33	0.42
0.7	17.4	0.99	0.36	0.36
0.8	13.3	0.76	0.33	0.25
0.9	10.3	0.59	0.23	0.14
1.0	8.2	0.47	0.08	0.04
	131.3			1.94

Table 1.

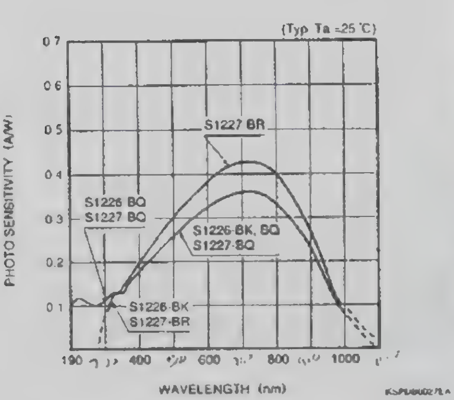


Figure 2. Photo Cell Response.

W1B Special Events Station a Success. Beau Bushor, N1MJD (left) and Mike Seguin, N1JEZ (right) send thanks to all who made W1B Special Events Station in Vermont a success. High points of the weekend included a RS-13 contact that allowed a ham to finish his WAS by giving him Vermont. W1B also worked some new contacts on AO-10 and AO-27 including 13 year-old KD5FAV.

ISS Amateur Radio Accommodations Meeting Held at the NASA Johnson Space Center in Houston, Texas

A series of extremely successful International Space Station (ISS) Amateur Radio accommodation meetings were held at the NASA Johnson Space Center in Houston from January 22-27. These pivotal meetings were sponsored by NASA and by Energia, the Russian space company that is building portions of ISS. The primary objectives of these meetings were to finalize the design development of the *Initial Station* amateur radio hardware for ISS and to develop a more effective understanding and advocacy of the Amateur Radio on the International Space Station (ARISS) program within NASA and Energia. In addition to representatives from NASA and Energia, the ARISS *Initial Station* hardware development teams from the US, Russia, Germany and Italy were invited to participate in the meetings. *The Initial Station* design, solidified during the July 1998 ARISS meeting in Surrey, England, consists of 2 meter and 70 cm handheld radios, a packet radio system and power supplies, provided by the US team, a Digitalker, provided by the German team, antenna feedthroughs and power and space accommodations provided by the Russian team and the development of an antenna system which is led by the Italian delegation. NASA will be providing a Space Shuttle launch to transport the Initial Station hardware to the ISS and has financially supported the flight qualification of the Initial Station Hardware. Some of the testing required by NASA and Energia to flight qualify this hardware includes the development of a safety analysis package, hardware performance testing, ISS interface testing, electromagnetic interference testing, and toxic chemical offgassing testing. Both NASA and Energia are intimately involved in the external outfitting of the planned antennas systems through special astronaut spacewalks or EVAs.

The following ARISS team members from various IARU and AMSAT organizations were invited to attend and participate in these meetings:

- Sergej Samburov, RV3DR, Representing Energia, AMSAT-Russia and ARISS-Russia
- Ron Parise, WA4SIR, Representing the ARISS-US Hardware Delegation
- Lou McFadin, W5DID, Representing the ARISS-US Hardware Delegation
- Frank Bauer, KA3HDO, Representing NASA, AMSAT-NA, and ARISS-US
- Matt Bordelon, KC5BTL, Representing NASA and ARISS-US
- Thomas Kieselbach, DL2MDE, Representing the ARISS-German Hardware Delegation
- Alberto Zagni, I2KBD, Representing the ARISS-Italian Hardware Delegation
- Fabrizio Bernardini, I0QIT, Representing the ARISS-Italian Hardware Delegation
- Luca Bertagnolio, IK2OVV, Representing the ARISS-Italian Hardware Delegation

During the meeting, Sergej Samburov, RV3DR, the President of AMSAT-Russia in Moscow and the Chief of the Cosmonaut Amateur Radio Department at Energia, confirmed that four dual-use antenna feedthroughs have been installed on the Russian Service Module. These dual-use feedthroughs are expected to support amateur radio operations and ISS proximity video capability during Russian and US spacewalks. He also confirmed his strong desire to work with the ARISS international partners to develop a single, coordinated amateur radio station on ISS.

Key NASA officials stated that they, too, need a single, international focal point to coordinate amateur radio development and operations on ISS if Amateur Radio on ISS is to have a future. During the meeting, these NASA officials were extremely pleased with the high level of flight hardware expertise and on-orbit operations knowledge that the ARISS international partners are providing to NASA and Energia. The ARISS international team was formed over two years ago to provide this single focal point to the space officials at NASA (US), Energia (Russia), NASDA (Japan) and ESA (Europe). Frank Bauer, KA3HDO, AMSAT-NA's Vice President for Human Spaceflight Programs, commented, "I was extremely impressed with the tremendous teamwork, camaraderie and cooperation that the ARISS International Partners exhibited during these pivotal meetings with NASA and Energia. Together we share a common vision to develop and operate a multifaceted amateur radio station on ISS that will be a great recreational outlet for the on-orbit crews, an exciting DXpedition station for hams on the ground and an outstanding educational outreach tool for students."

In the near future, additional information from these meetings will be provided including discussions on:

- ARISS Initial Configuration & Delivery Schedule to ISS
- Antenna System Design
- Antenna Locations on Service Module and initial plans for ARISS EVAs
- Meetings with NASA Senior Managers
- Digitalker design
- ARISS Frequencies
- Future installation of an SSTV system
- Express Pallet opportunities

The ARISS hardware team discussed and reaffirmed their long planned commitment to solicit proposals from the Amateur Radio community to develop follow-on amateur radio hardware for ISS. Proposals chosen to proceed forward would then be coordinated through a NASA/Energia employee-based radio working group that would negotiate power, volume and operations scenarios for the proposed equipment. The ARISS international team is composed of representatives from the IARU and AMSAT societies in Russia, Italy, Germany, England, France, Canada, Japan and the US. The Space Amateur Radio EXperiment (SAREX) Working Group provides the US hardware and administrative representation to the ARISS international team. Within the US, they coordinate the US hardware development, operations and educational outreach activities for the ARRL, AMSAT-NA and NASA.

AMSAT-NA Board of Directors Nominations

It is time to submit nominations for AMSAT-NA Board of Directors. AMSAT member societies or five current individual members may make nominations of fellow members to serve a two-year term. Four seats on a seven-member board must be filled this year. The board members whose terms are expiring are: Dick Daniels W4PUJ, Joe Holman AD7D, Bill Tynan W3XO and Stan Wood, WA4NFY. Please be sure that anyone you nominate understands that meeting attendance is necessary. There are generally two Board of Directors meetings per year (Spring and Fall). Nominations should be marked Board of Director Nomination and sent to AMSAT, 850 Sligo Ave, Suite #600, Silver Spring MD 20910-4703 and must arrive by June 15, 1999.

King Hussein bin Taal, JY1 SK

AMSAT members around the world were saddened to learn of the death of King Hussein, JY1. King Hussein was an AMSAT Life Member (LM1981) and staunch supporter of AMSAT efforts. Shortly after his death, amsat-bb was filled with recollections about his AMSAT involvement.

Tom Clark, W3IWI provided his personal recollections of JY1. Back in W3IWI's DXing days he recalled the magic of the rare QSO with JY1 as his presence on HF would create a world-class pileup.

Clark also recalled that in May 1980 when he was President of AMSAT, the Phase-3A spacecraft was lost during launch. "It was a black day for us and we were fighting to keep an amateur satellite program alive. I received a phone call late one night from Bruce *Blackie* Blackburn, JY9BB/W4TA (AMSAT LM50) who served as a communications/technology advisor to the King. Blackie told me that the King was concerned about Amateur Radio's loss and asked a lot of questions about our recovery plans and needs. Blackie ended the call with a comment to the effect "I'll be back with you in a couple of weeks, and I may have some good news."

The next week the newspapers carried a small news note that the King was in the US to buy some jet planes for Jordan. A couple of days later, the telephone rang again and it was Blackie calling from Los Angeles. He asked me to hold and this wondrous voice came on the line saying "Tom – it is a pleasure to talk to you at last. This is JY1. I wanted to tell you how proud we are of AMSAT's efforts and how sad we are about the loss of Phase-3A. I would like to offer some help, so I'm sending you a contribution."

We exchanged a few minutes more of chit-chat, and Blackie came back on the line and said "Tom, the King's contribution to AMSAT is a check for $10,000. I have it in my hand. Where should I send it?"

Not only did JY1's generous contribution provide needed financial support, it was very important in helping the AMSAT folks to rebuild their morale. AO-10 was the result of JY1's generous outreach.

A few years later in 1983, AMSAT made its first venture into Manned Space Flight with Owen Garriot's (W5LFL flight). We arranged for a *private* JY1-W5LFL QSO while the shuttle was flying over the Middle East. To hear the tapes of that QSO was a fantastic experience.

Pat Kilroy's, WD8LAQ life was directly touched by King Hussein on 1995 October 20. Pat answered his CQ on 14.295 MHz and enjoyed a three-minute *ragchew*. "JY1 was traveling aeronautical mobile, enroute to the United Nations in New York City. He insisted on me addressing him simply as Hussein. In one of the oldest traditions in Amateur Radio, Hussein upheld that this kinship transverses not only age and nationality, but also between citizen and head of state!"

Pat's QSO with JY1 occurred less than five hours after the launch of Columbia on STS-73 (how appropriate!), the USML-2 mission. Hussein was monitoring the WA3NAN space shuttle retransmission frequency as the 16-day mission unfolded.

His elegant QSL card was prized. AMSAT Area Coordinator Bruce Paige, KK5DO, in Houston, worked JY1 while the king was in the US last summer. ''That was a very exciting moment for me,'' he said. The card can be viewed via *http://www.amsatnet.com/jy1.html*

AMSAT expresses its sincere sympathy to the family of King Hussein and the citizens of Jordan on the loss of their leader.

King Hussien bin Taal, JY1, 1935-1999

Call for Papers for the 17th Space Symposium and AMSAT-NA Annual Meeting

The 17th AMSAT-NA Annual Meeting and Space Symposium will be held October 8-11, 1999 at the Hanalei Hotel in San Diego, California, USA. This is the first call to authors who wish to present papers at the Symposium and that will be printed in the proceedings. The subject matter of the papers should be topics of interest to the Amateur Radio satellite service. Key dates in calling for and submitting papers are:

One page abstracts are due no later than May 1, 1999. Authors will be advised by e-mail or postal mail shortly after June 1, 1999 regarding whether their paper has been accepted.

Camera ready copy of accepted papers is due no later than August 1, 1999. Papers will only be superficially edited and will be printed generally as submitted. Authors are requested to provide an electronic copy of their presentations preferably in any version of Word or WordPerfect in the event corrections are required at the last minute.

Please send abstracts to Duane Naugle, KO6BT via email to: ko6bt@amsat.org, or via postal service to: 4111 Nemaha Drive, San Diego, CA, 92117-4522, USA.

Receipt of submissions will be confirmed and proceedings of the Symposium will be printed by the ARRL and made available at and after the meeting. Also, if you do not wish to present a paper, but have a topic of interest, please submit the topic and perhaps arrangements can be made for a presentation.

Information regarding San Diego area attractions and details on arrangements for the 17th Space Symposium and AMSAT-NA Annual Meeting may soon be found on the web at: http://www.amsat.org

For additional information on this press release contact: Duane Naugle, KO6BT via email at ko6bt@amsat.org

Results of Annual Straight Key Night

Ray Soifer, W2RS reports that AMSAT-NA's 27th Annual Straight Key Night on OSCAR, held 1 January 1999, was quite a success, with lots of fun had by all.

Here is this year's list of Best Fist winners. Each amateur listed received one or more nominations from Straight Key Night participants:

- Richard Limebear, G3RWL, England
- Keith Baker, KB1SF, Ohio
- Cliff Buttchardt, K7RR, California
- Frank Wiesenmeyer, K9CIS, Illinois
- Russell Hack, NM1K, Connecticut
- David Perry, N0IBT, Colorado
- Miroslav Kasal, OK2AQK, Czech Republic
- Jim Lucas, W3JIM, Maryland

Our thanks to all who took part. We hope you're able to join us for the 28th annual event, which will celebrate the arrival of the millennium on 1 January 2000. Please be sure, though, to run your orbital predictions beforehand. We hope the Y2K bug doesn't strike your computer, but even if it does, there's always the old reliable straight key!

Texas Potato Masher Antenna

Jerry Brown's, K5OE interesting article on the Texas Potato Masher in the January/February issue of *The AMSAT Journal* drew a series of questions, comments, and answers on amsat-bb:

In Table 1 you refer to a test procedure using a coax tee and dummy load. Would you mind explaining?

This procedure involves using a coax tee (center) on the ANT jack of your SWR meter. On one side of the tee, place a 50 Ohm dummy load (I use a short piece of coax and two 100 Ohm, 10 Watt resistors). On the opposite side, place the ¼ wavelength piece of coax, with the end shield shorted to the center conductor. Trim the coax for minimum SWR. At the resonant frequency, the shorted coax looks like a very high Z to the signal and is ignored and all the power is fed into the dummy load. I find this is a little *broad* at 70 cm, so you might try using ½ wavelength of coax and leaving the end open—then cut in half after trimming. Either one works OK.

Where the two loops cross at the far end of the antenna, I presume they are not electrically connected.

Correct. I used insulated #10 wire and applied a drop of glue to the point where they crossed. By the way, modeling shows the shape of the rectangles affects the resonant frequency almost more than the length of wire (when the length is close to resonance). If you have trouble getting a low SWR using the lengths in the article, adjust the length-to-width a little and see if that helps.

Is the distance that the two square elements are from each other on the top where they pass through the PVC pipe critical? They almost look like they are touching but I don't think you would want that?

They are touching, but the wire is insulated (#10 house wiring). I put a drop of Super-Glue on the 70 cm version to keep it tightly in place since I didn't extend the *mast* that far. Surprisingly, the Super-Glue has held up for six months in the harsh Texas sun without failure. On the 2 meter version, I slotted the end of the PVC mast with a hacksaw and pressed the wires into the slot to hold them firmly in place.

I am glad to see someone using the 1/2 wavelength cable technique. I use it a lot even on HF.

If all SWR meters were really accurate, that step wouldn't be necessary. But, if you are using an impedance bridge (or an MFJ or Autek Antenna Analyzer), then it is absolutely necessary to avoid the transformer effect in the testing line.

Is it absolutely necessary to determine the spacing of the radials from the driven elements or could I use the values for the distances in the article?

The values in the article are pretty close and were right on the money from where my research said they would be. I used a field-strength meter to determine the position. Normally, having a parasitic element this close to a driven element is not desirable (e.g., a Yagi beam) because it lowers the feedpoint impedance too much *and* it severely narrows the usable bandwidth of the antenna. Neither of these

are a problem here because the input impedance is already very high and the satellite frequency bands are very narrow. A plus for a close reflector is good F/B ratio. I only suggested you *play* with the distance to get a perfect match on the SWR meter. SWR was important to me because I have about 50' of 9913-flex to both antennas and my 70 cm preamp is about 20' from the antenna (in the attic). Every dB counts!

Someone wrote that the R. F. Connection carries RG-62 in both PVC and plenum versions. Call 800-783-2666.

From front page photo, looks like the phasing line is inside of the PVC. Is this so?

Yes, the phasing line is inside the PVC *mast*.

What is the spacing between the 2 meter and 440 antennas?

Well, I have to admit I did no scientific research or testing on the spacing. I just cut the PVC *boom* pieces to get a balance at the PVC tee I used above the main rotor mast. I am guessing it is about 1 meter between the antenna feedpoints. I doubt that it is critical at all.

Do you have any other construction hints? I have built a 2 mtr and 440 egg beater, and they do work, but I would like to try the masher.

Yes! If you already have working eggbeaters, try just adding the reflector elements (assuming you don't have them now) behind the eggbeater feedpoint and a rotator. You will be in business with very little effort. If you get too high an SWR with the eggbeaters and the reflectors added, try re-shaping the elements to a square.

AMSAT-NA Strategic Planning Team Formed

Under the guidance of Bill Burden, WB1BRE, AMSAT-NA Vice President for Strategic Planning, AMSAT's strategic planning process is about to re-commence. The initial idea is to review the current AMSAT-NA mandate and then present those findings to the Board of Directors, either confirming the current AMSAT-NA mandate — or to make appropriate changes. This action will require a considerable amount of work by those involved, but according to AMSAT-NA Executive Vice President Robin Haighton, VE3FRH, "both AMSAT-NA President Keith Baker and I consider this to be an essential action that must be completed before the next annual AMSAT-NA meeting in San Diego." At that time, added VE3FRH, "any proposed changes may be placed in front of the general membership."

Team members were chosen from active members of AMSAT-NA, representative of the general membership and the geographical areas served by AMSAT-NA itself. Current team members are:

- Keith Baker, KB1SF
- Steve Bible, N7HPR
- Bill Burden, WB1BRE, Chair
- Ken Ernandes, N2WWD
- Bdale Garbee, N3EUA
- Robin Haighton, VE3FRH
- Dan James, NN0DJ
- Russ Tillman, K5NRK

Stay tuned to ANS for further developments of the Strategic Planning Team.

Satellite Orbital Elements

by Ray Hoad, WA5QGD

Satellite	AO-10	FO-20	RS-12/13	AO-27	RS-15	FO-29	UO-11	MIR
Catalog Number	14129	20480	21089	22825	23439	24278	14781	16609
Epoch Time	99054.15772777	99070.10112750	99070.18820086	99070.73608115	99069.83636789	99069.90753196	99069.93467515	99070.76449324
Element Set	562	125	141	709	391	245	137	303
Inclination	27.0677	99.0341	82.9248	98.4707	64.8139	98.5473	97.9163	51.6627
RA of Node	42.3759	283.4581	169.935	138.4263	211.4478	34.2382	39.1002	123.2444
Eccentricity	0.6010043	0.0541168	0.0029392	0.0008228	0.0154851	0.0351579	0.0011893	0.0011924
Arg of Perigee	292.4966	26.9054	340.899	180.1562	10.751	348.8266	139.4228	228.3689
Mean Anomaly	23.719	335.9045	19.1064	179.9617	349.6665	10.521	220.7866	131.6335
Mean Motion	2.05868921	12.83250532	13.74124535	14.27863886	11.27533646	13.52663063	14.70265616	15.72455405
Decay Rate	-0.00000171	0.00000027	0.00000115	0.00000152	-0.00000038	0.00000024	0.00001129	0.00038351
Epoch Rev	11804	42575	40595	28433	17315	12652	80405	74607
Satellite	UO-14	AO-16	DO-17	WO-18	LO-19	UO-22	KO-23	ISS
Catalog Number	20437	20439	20440	20441	20442	21575	22077	25544
Epoch Time	99070.19852047	99070.19401310	99070.25525721	99070.19972012	99070.25376391	99070.14141878	99070.62635094	99070.89422766
Element Set	437	244	215	232	220	938	815	387
Inclination	98.4627	98.4902	98.4968	98.494	98.4975	98.2127	66.0788	51.5951
RA of Node	146.3689	151.0142	152.4778	152.2248	153.3761	115.1901	261.0242	327.6466
Eccentricity	0.0011365	0.0011401	0.0011746	0.0012167	0.0012526	0.0007501	0.0014529	0.0004483
Arg of Perigee	141.9304	144.0084	143.4161	144.0457	142.8504	148.7605	248.8623	206.7134
Mean Anomaly	218.2677	216.1865	216.7824	216.1545	217.3547	211.4027	111.0842	153.3577
Mean Motion	14.3012785	14.30164966	14.30318517	14.30270872	14.303975	14.37272878	12.86319416	15.58518788
Decay Rate	0.00000227	0.000002	0.0000021	0.00000206	0.00000205	0.00000241	-0.00000037	0.00016273
Epoch Rev	47654	47656	47661	47660	47664	40125	30909	1741
Satellite	IO-26	KO-25	TO-31	GO-32	SO-33	PO-34	SO-35	Phase 3D (est)
Catalog Number	22826	22828	25396	25397	25509	25520	25636	99934
Epoch Time	99070.16406359	99070.74378466	99070.21765487	99070.16301423	99070.19340899	99070.18302035	99070.17476917	96260.25523447
Element Set	720	686	133	149	36	66	75	3
Inclination	98.4732	98.4683	98.7686	98.7666	31.4445	28.4634	96.4755	60.0203
RA of Node	138.3083	138.9933	144.3524	144.2398	342.2489	11.1296	21.344	342.7876
Eccentricity	0.0008319	0.0010117	0.0001683	0.0001488	0.0368526	0.0007228	0.0152474	0.6752895
Arg of Perigee	184.283	163.3601	31.1546	53.7341	4.818	348.9642	203.4622	180.1221
Mean Anomaly	175.8279	196.7913	328.9741	306.3974	355.5855	11.0789	155.9568	179.5089
Mean Motion	14.27982818	14.28346188	14.22338346	14.22224965	14.23851251	15.03380359	14.40866597	1.51063968
Decay Rate	0.00000152	0.00000193	-0.00000044	-0.00000044	0.00001026	0.00002002	0.00000142	0.00002
Epoch Rev	28427	25250	3469	3470	1963	1994	226	2

Comos Award Available

About a year ago, Bruce Paige, KK5DO sent to Moscow for Cosmos Awards for three stateside hams. In February, KK5DO received the awards back in the United States and forwarded them to the following respective hams:

- Mike Seguin, N1JEZ (Award #49)
- Robert, KB4NVD (Award #50)
- Bob, WE1U (Award #51)

They were issued in December, 1998, while KK5DO received Award #6, issued in March, 1997. As you can see, the award has become very popular.

If you would like to apply for the award, KK5DO is accepting applications. There will be someone going to Moscow and will handcarry the paperwork.

Qualifications: You must have 100, 200 or 300 contacts with QSL cards in hand on LEO satellites.

Print out a list of these contacts and have the contacts on the list certified by two other licensed radio amateurs. They must verify that you have all the cards for your contacts. Then send that list with signatures and a statement *I would like to apply for the Cosmos Award. Enclosed are XXX (insert 100, 200, or 300) contacts for Diploma X (enter 1, 2, or 3).*

Sign your name and call sign, enclose $5 for the certificate, and put it in an envelope and mail it to Bruce Paige, KK5DO, PO Box 310, Alief, TX 77411

KK5DO will then take all these envelopes and forward them to my friends at NASA who will carry them over for Karen, RA3APW and his wife Natalie, RW3ABI to carry to the Central Radio Club for processing. Then, someday, when someone returns from Moscow to the U.S., KK5DO will forward them back to you. This last trip, Sergei Samburov, RV3DR (President of AMSAT Russia) carried them from Moscow as he was in Houston for an ARISS meeting.

Please let KK5DO know via e-mail (*kk5do@amsat.org*) if you are going to apply for the award. That way, if he should have someone going over sooner than anticipated, he can notify you.

Field Ops Update: AMSAT Area Coordinators Listing

Barry A. Baines, WD4ASW, *wd4asw@amsat.org*

Once again we present our annual listing of AMSAT's Area Coordinators. In this issue you will find a listing of the 143 Area Coordinators (plus country representatives) who donate their time and energy to help represent AMSAT within their respective communities. These volunteers may give programs to local clubs, serve as 'Elmers' to folks getting started in amateur satellites, and establish AMSAT nets on local repeaters. Other activities that Area Coordinators have done include organizing local AMSAT gatherings and supporting AMSAT Field Day activities. They serve as 'Ambassadors of AMSAT' in that they become the local contact for people needing information on the amateur satellite program. Through close coordination with AMSAT Office Manager Martha Saragovitz, who provides AMSAT banners and materials when requested, they represent AMSAT at hamfests and swapmeets as well as lead AMSAT presentations at these gatherings. For example, a number of volunteers have given AO-27 demonstrations at hamfests, which always generates interest and enthusiasm and which demonstrates to their communities what the amateur satellite program is all about.

AMSAT has been blessed by a number of people who have stepped forward to volunteer as Area Coordinators around the country. We currently have Area Coordinators in 47 states and 4 Canadian Provinces, as well as Guam, Puerto Rico, and the U.S. Virgin Islands. Given the need to show the flag throughout North America, we continue to look for volunteers everywhere. You will note that there are several states where we don't have a designated Area Coordinator (Iowa, South Dakota, Wyoming). There are 13 other states in which there is only one Area Coordinator. Even in states where we have multiple Area Coordinators, we still lack Area Coordinators in heavily populated areas nor do we enjoy even distribution of Area Coordinators around a given State. Field Operations representation is particularly needed in areas such as California (Los Angeles), Florida (Panhandle), Illinois (Chicago), Massachusetts (Springfield-West), New Jersey (Newark and the Northern half of the State), New York (NYC and suburbs), Ohio (Cincinnati, Cleveland), Pennsylvania (Allentown/Northeast), Virginia (Tidewater Area), and the DC area. In Canada, we can also use support in the Eastern Provinces (Quebec, Newfoundland, New Brunswick, Nova Scotia) as well as Saskatchewan and Manitoba.

The importance of having Area Coordinators in these areas as well as improving coverage in existing areas cannot be understated. AMSAT's ability to increase interest in the amateur satellite program is dependent in part upon creating and maintaining both individual interest and general knowledge within the Amateur Radio community of using amateur radio satellites. During the past year AMSAT was not represented at several large hamfests because we didn't have points of contact close enough to take advantage of these opportunities. Likewise, when contacted by several clubs looking for local AMSAT representatives to provide a club presentation or for technical support, we could not meet their requests on the local level. Our lack of volunteers to address these situations results in failure to develop support for the amateur satellite program, lost membership opportunities, and missed revenue through distribution of AMSAT materials. More importantly, not being seen means that our message is not being heard.

The qualifications needed for being an Area Coordinator are simple: You must be a current member of AMSAT-NA, be willing to work with people, and have an interest in representing the organization as your time and interests permit. As an area coordinator, how much time you devote to representing AMSAT as well as the types of activities you perform (hamfests, local AMSAT nets, making presentations, etc.) is up to you. The key is to have people designated throughout North America who can respond to local queries, allow AMSAT to generate local interest, and help spead the workload. In order to maintain contact with members of our Field Ops Team and provide them with support materials as needed, we also require each Area Coordinator have Internet electronic mail capability. E-mail provides an easy and cost effective avenue for distributing information, sharing ideas, and responding to requests for support. Given the variety of satellites in current use and the diversity of interests, Area Coordinators are not expected to know everything about the amateur satellite program. What is important is that each Area Coordinator be willing to find answers to questions and follow up with individuals looking for assistance. That's why we require electronic access, so that everyone can get information from other Area Coordinators and respond to queries in a timely manner.

If you are interested in serving as an Area Coordinator or learning more about the Field Organization, please contact me via: e-mail: *wd4asw@amsat.org*, telephone: 904-398-5185 (home) or 904-359-1933 (work) facsimile: 904-399-3225 (home).

AMSAT-NA Area Coordinators

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WY							
US Territories							
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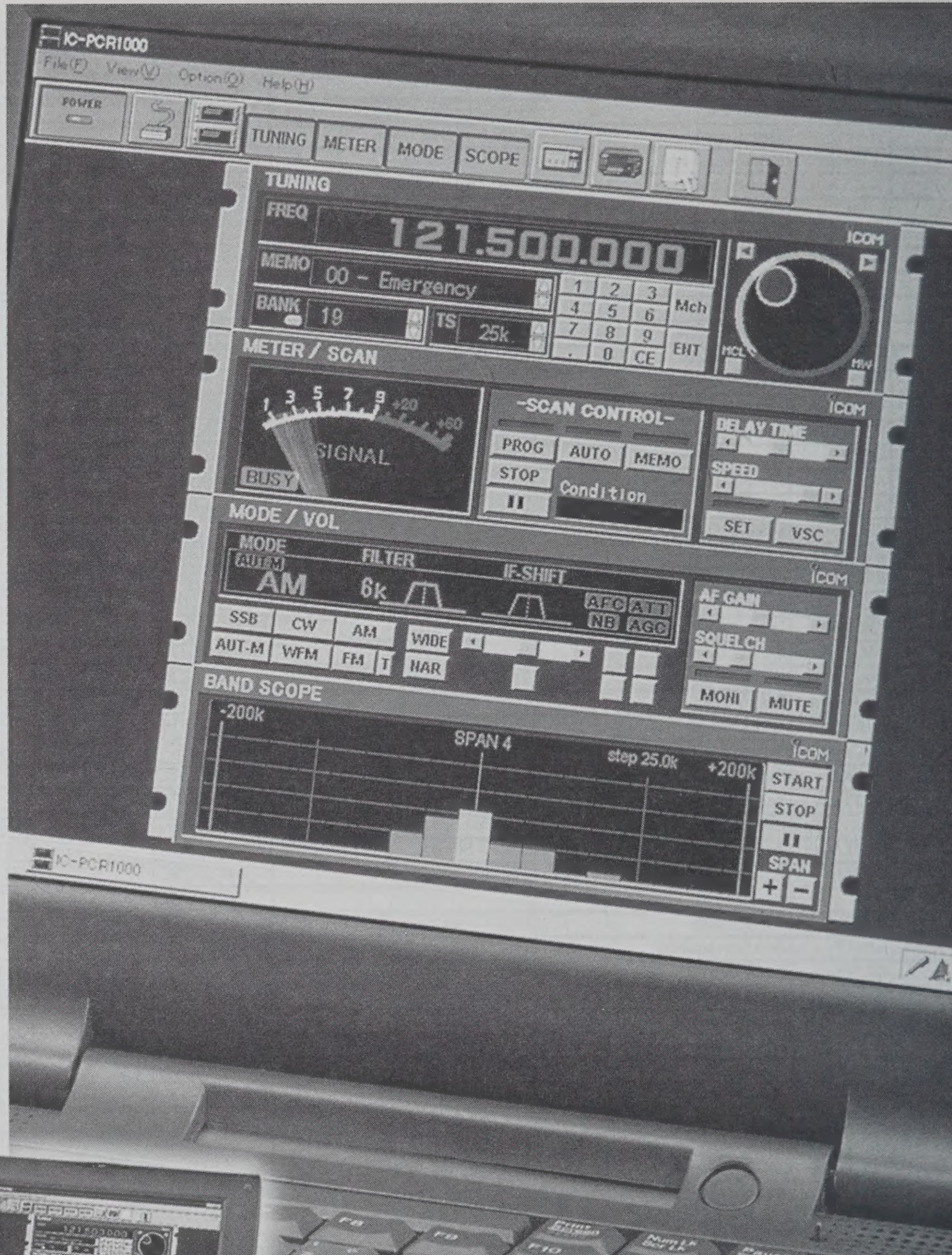
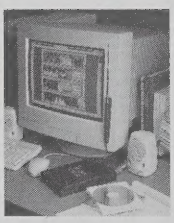
	HR2KOS	Ricardo 'Rick' Denis	P.O. Box 1224	San Pedro Sula, Honduras	21105	(504) 53-0136	hr2kos@amsat.org
	A71EY	Mohamed Althani	P.O. Box 2260	Qatar			a71ey@amsat.org

WORLD WIDE RADIO

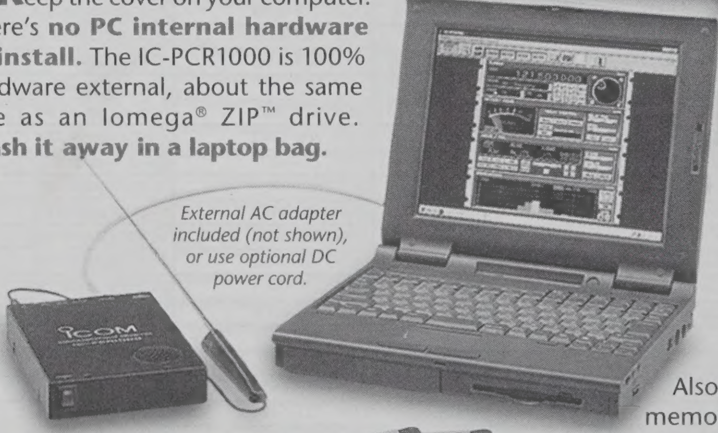
IN A LITTLE BLACK BOX





Combine powerful listening performance with go-anywhere PC convenience. ICOM's IC-PCR1000 wide band **multimedia** receiver is now available.

Keep the cover on your computer. There's **no PC internal hardware to install.** The IC-PCR1000 is 100% hardware external, about the same size as an Iomega® ZIP™ drive. **Stash it away in a laptop bag.**



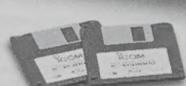
External AC adapter included (not shown), or use optional DC power cord.

IC-PCR1000

100% PC External World Wide Receiver

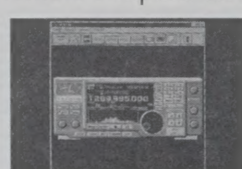
Designed for Windows® 3.1 *and* Windows® 95

Take the black box with you to work, to school, on business trips, even while out camping or on a boat. **Catch receiver activity while working in foreground applications.**



The big reception on this little radio will surprise you. Monitor **500 kHz – 1300 MHz*** on **all modes** (AM/FM/WFM/SSB/CW).

Also enjoy: unlimited memory channels, real time band scope, tone squelch (CTCSS) decode, 5 DTMF memories for advanced remote computer control, a **9600 baud** data connection point for third party applications (like weather fax), and **optional DSP.**



Everything's included to get you started. And the latest software is always available for free downloading on the ICOM America web site. To get it, and to find your nearest authorized IC-PCR1000 dealer, visit **www.icomamerica.com** today. Or, for more information, call for a free brochure, 24 hours a day: **425-450-6088**

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